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PLASTIC PROCESSOR

Learner Guide

National Vocational Certificate Level 4

Version 1 - September, 2018

NAVTTC

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Introduction

Welcome to your Learner's Guide for the Plastic Processor level 4. It will help you complete the training and go on with further study or go straight into employment.

The Plastic Processor level 4 training is to engage young people with a program of development that will provide them with the knowledge, skills and understanding to start their career in Pakistan. This qualification will not only build the capacity of existing workers of manufacturing engineering sector but also support the youth to acquire skills best fit in manufacturing industry.

The main elements of your learner's guide are:

- **Introduction:**
  - This includes a brief description of your guide and guidelines for you to use it effectively
- **Modules:**
  - The modules form the sections in your learner's guide
- **Learning Units:**
  - Learning Units are the main sections within each module
- **Learning outcomes**:
  - Learning outcomes of each learning units are taken from the curriculum document
- **Learning Elements:**
  - This is the main content of your learner's guide with detail of the knowledge and skills (practical activities, projects, assignments, practices etc.) you will require to achieve learning outcomes stated in the curriculum
  - This section will include examples, photographs and illustrations relating to each learning outcome
- **Summary of modules**:
  - This contains the summary of the modules that make up your learner's guide
- **Frequently asked questions**:
  - These have been added to provide further explanation and clarity on some of the difficult concepts and areas. This further helps you in preparing for your assessment.
- **Multiple choice questions for self-test**:
  - These are provided as an exercise at the end of your learner's guide to help you in preparing for your assessment.

Frequently Asked Question

1. What is Competency Based Training (CBT) and how is it different from currently offered trainings in institutes?	Competency-based training (CBT) is an approach to vocational education and training that places emphasis on what a person can do in the workplace as a result of completing a program of training. Compared to conventional programs, the competency-based training is not primarily content based; it rather focuses on the competence requirement of the envisaged job role. The whole qualification refers to certain industry standard criterion and is modularized in nature rather than being course oriented.
2. What is the passing criterion for CBT certificate?	You shall be required to be declared "Competent" in the summative assessment to attain the certificate.
3. How can I progress in my educational career after attaining this certificate?	You shall be eligible to take admission in the National Vocational Certificate Level-5 in Plastic Processor. You shall be able to progress further to National Vocational Certificate Level-5 in Plastic Processor, and take admission in a level-5, DAE or equivalent course. In certain case, you may be required to attain an equivalence certificate from The Inter Board Committee of Chairmen (IBCC).
4. What is the importance of this certificate in National and International job market?	This certificate is based on the nationally standardized and notified competency standards by National Vocational and Technical Training Commission (NAVTTC). These standards are also recognized worldwide as all the standards are coded using international methodology and are accessible to the employers worldwide through NAVTTC website.
5. Which jobs can I get after attaining this certificate? Are there job for this certificate in public sector as well?	You shall be able to take up jobs in the manufacturing and Plastic Processing Industries as a processor for the production of plastic parts and household goods.
6. What are possible career progressions in industry after attaining this certificate?	You shall be able to progress up to the level of shop supervisor after attaining sufficient experience, knowledge and skills during the job. Attaining additional relevant qualifications may aid your career advancement to even higher levels.

7. Is this certificate recognized by any competent authority in Pakistan?	This certificate is based on the nationally standardized and notified competency standards by National Vocational and Technical Training Commission (NAVTTC). The official certificates shall be awarded by the relevant certificate awarding body.
8. Is on-the-job training mandatory for this certificate? If yes, what is the duration of on-the-job training?	On-the-job training is not a requirement for final / summative assessment of this certificate. However, taking up on-the-job training after or during the course work may add your chances to get a job afterwards.
9. What is the examination / assessment system in this program?	Competency based assessments are organized by training institutes during the course which serve the purpose of assessing the progress and preparedness of each student. Final / summative assessments are organized by the relevant qualification awarding bodies at the end of the certificate program. You shall be required to be declared "Competent" in the summative assessment to attain the certificate.
10. Does this certificate enable me to work as freelancer?	You can start your small business as a Plastic Processor. You may need additional skills on entrepreneurship to support your initiative.

PLASTIC PROCESSOR

Module-7

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Modules

Module 7: 072200919 Perform Off Tool Sampling

Objective of the module: The aim of this module to identify the competencies required to perform off tool sampling in accordance with job order/sheet's guidelines

Duration: 150 hours **Theory:** 30 hours **Practical:** 120 hours

Learning Unit	Learning Outcomes	Learning Elements	Duration	Materials Required	Learning Place
LU1: Ensure type of tool	**The trainee will be able to:** Select tool as per given job card/ work order Select machine as per tool according to job card/ work order. Verify selection of tool/ Machine according to job requirement Install the tool on selected machine as per installation manual. Connect auxiliaries with tool as per machine operation manual.	i) Machine knowledge ii) Tool selection iii) Tool lifting and installation iv) Auxiliaries Equipment such as hydraulics, pneumatics, electrical and heating systems	**Total** 10 hours **Theory:** 2 hours **Practical:** 08 hours	Basic Hand tools Moulding Machine Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic supplies, such as grease, oil, cleaning agent, emery paper etc.	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

LU2: Set machine parameters	**The trainee will be able to:** Set parameters as per Process Parameter Sheet (PPS) of machine and job card. Check safeties of Mould and machine for safe operation.	i) Moulding cycle from feeding to ejection • Set processing parameters as per job card • Ensure desired temperatures are achieved • Ensure raw material is ready for processing (De-humidified, etc.) • Ensure all peripheral equipments are working properly (oil pump, air filter, hydraulics, motors, pneumatics, etc.) ii) Recognize screw configurations • Check shot size and speed • Check injection pressure and other parameters	**Total** 40 hours **Theory:** 08 hours **Practical:** 32 hours	Basic Hand tools Moulding Machine Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic supplies, such as grease, oil, cleaning agent, emery paper etc.	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU3: Execute Dry Run operation	**The trainee will be able to:** Check open/close Mould manually for dry run operation. Ensure temperature of heaters as per SOP Check Ejector mechanism as per execution operation	i) Knowledge and understanding of mould and it's mechanism ii) Understanding of hydraulic and pneumatic systems iii) Manual operation of injection mounding machine iv) Identify runner, gate and clamping v) Identify two plate, slider mould, hot runner mould vi) Identify and set up part ejection in the mould	**Total** 30 hours **Theory:** 06 hours **Practical:** 24 hours	Basic Hand tools Moulding Machine Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic supplies, such as grease, oil, cleaning	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

				agent, emery paper etc.	
LU4: Produce Sample	**The trainee will be able to:** Purge material in manual mode as per job requirement. Run continuous operation on semi-auto/ auto mode till the required physical appearance achieved. Verify the physical appearance of sample as per SOP of quality standard	i) Recognize machine controls ii) Learn to adjust temperatures from feed zone to injection point iii) Learn to adjust injection pressure iv) Perform Dry-run v) Perform Semi-auto operation vii) Maintaining product quality as per specifications • Be able to measure components for identification of dimensional defects • Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc. viii) Recognize different defects and their causes • Be able to visually identify commonly occurring defects, such as gating, flashing, orange-peel, etc. ix) Gain knowledge of rectification of commonly occurring defects.	**Total** 30 hours **Theory:** 06 hours **Practical:** 24 hours	Basic Hand tools Moulding Machine Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic supplies, such as grease, oil, cleaning agent, emery paper etc.	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU5: Verify sample specification	**The trainee will be able to:** Check dimensions of the sample as per drawing specification. Check assembly of the sample as per job card.	i) Measuring & marking tools • Understand QC protocols • Understand and appreciate the importance of producing products as per specification • Produce samples as per standard ii) Be able to visually identify defects compared to sample specimen	**Total** 10 hours **Theory:** 2 hours **Practical:** 8 hours	Basic Hand tools Moulding Machine Machine Mould Utility documentation. Service Manuals.	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR**

	Produce the required sample size in auto mode according to pilot lot.	• Be able to measure components for identification of dimensional defects • Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc. iii) Check if and when the part is supposed to fit in to other components. iv) Ensure dimensional and mechanical accuracy		Operational Manuals. Basic supplies, such as grease, oil, cleaning agent, emery paper etc.	Visit to a training institute with relevant facilities
LU6: Generate Sample report	**The trainee will be able to:** Prepare the sample report on given format. Submit the sample report for approvals as per standard	i) Production report writing • Understand the importance of reporting accurate production quantity and specifications • Be able to fill-in relevant production reports • Report sample size and percentage of defected products	20 hours **Theory:** 4 hours **Practical:** 16 hours	Basic Hand tools Moulding Machine Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic supplies, such as grease, oil, cleaning agent, emery paper etc.	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU7: Take approval for processing	**The trainee will be able to:**	i) Operation of machine in semi-auto and auto mode ii) Optimization of machine parameters for production	**Total** 10 hours **Theory:** 02 hours	Basic Hand tools Moulding Machine	Classroom with multimedia aid and flip charts **EITHER**

	Execute sampling process after approval received. Maintain process parameters for quality production.	iii) Data sharing with relevant departments • Understanding the concept of producing accurate data and benefits of the same on a larger scale	**Practical:** 08 hours	Machine Mould Utility documentation. Service Manuals. Operational Manuals. Basic supplies, such as grease, oil, cleaning agent, emery paper etc.	Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

Examples and Illustrations:

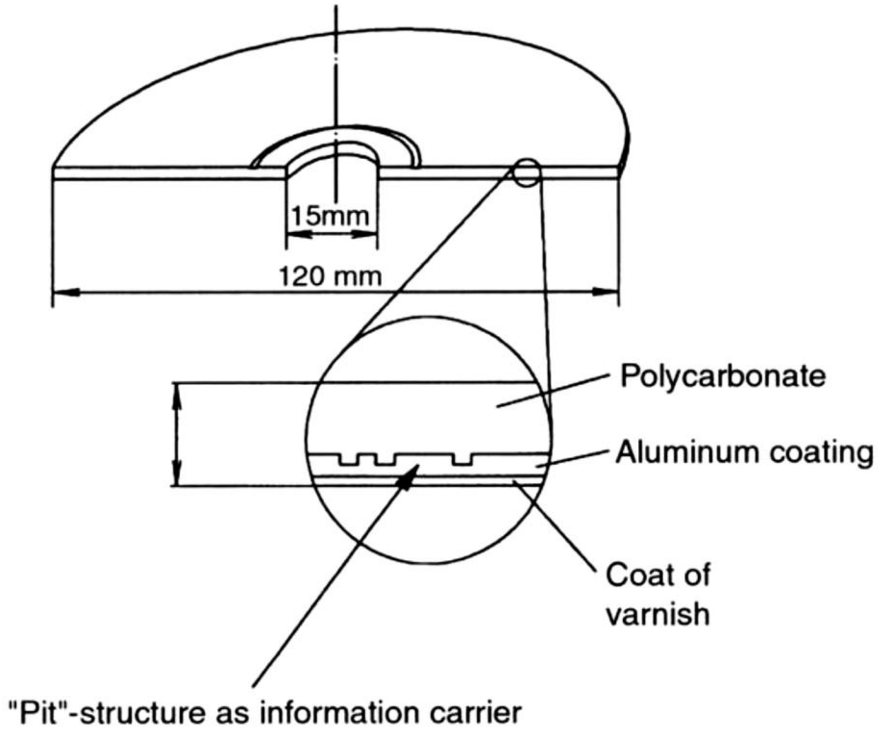
For more details please refer to these books:

1) Training in Injection Moulding, 2nd Edition, by HANSER Publishers, Munich.
2) Understanding Polymer Processing, by Hanser Publishers, Munich
3) Extrusion: The Definitive Processing Guide and Handbook by © 2005 William Andrew Publishing
4) The Dynisco Extrusion Processors Handbook 2nd Edition by John Goff and Tony Whelan, The DYNISCO Companies
5) Practical Guide to Blow Moulding Technology by Norman C. Lee, © 2006 Rapra Technology Ltd.
6) Handbook of Troubleshooting Plastics Processes by © 2012 Scrivener Publishing LLC, Chapter 18: Compression Moulding
7) Presentation on Compression Moulding, 2008 AMD 2927, IIT Delhi, by Chandra Shekhar Thakur

Some key introductions to Injection Mouding:

the most important processing method for plastics	In comparison to the classic methods of metal fabrication and processing (such as milling, drilling, turning, etc.), injection molding represents a manufacturing method which is still young. However, injection molding has already become the most important method in plastics processing technology
plunger machines	The early injection molding machines were plunger machines. The plastic was melted in a heated cylinder and injected into the mold by the plunger. This type of machine is no longer found, except in research laboratories, for making very small quantities of experimental articles.
screw principle	Most modern injection molding machines operate on the screw principle. The molding compound is melted by band heaters and the frictional heat produced by the rotating screw, In the injection operation, the rotation of the screw is stopped, and the screw begins to function as a plunger. The screw must therefore fulfill the functions of conveyance, mixing, and injection. Separate plasticating screws and injection plungers are often used in the processing of elastomers.
thermoplastics	Thermoplastics represent the most important group of plastics to be processed in injection molding. Typical injection-molded parts made from thermoplastics include automobile hubcaps and bumpers, gears in kitchen appliances, screw-on caps and lids, bottle crates, printer cartridges, and ball-point pens.
Compact Disk (CD)	Even the Compact Disk (CD) is produced from polycarbonate (PC) by the injection molding method.
elastomers	Another important materials group are the cross-linked polymers, such as elastomers and thermosets. Typical elastomer molded parts manufactured by injection molding include bellows, shock-absorbing components in automobiles, seals, and molded tubes,
thermosets	Thermosets consist of densely crosslinked polymers, that can also be processed by injection molding. Thus, produced articles are used in boats, in the automotive field and in the electrical industry (insulation). Thermoset moldings find particular application, where their non-conductive properties and heat-resistance are essential. Injection molding provides a cost-effective mass-production process of articles for the electrical industry.
Injection Molding -A Discontinuous Single-Stage Process	
primary processing method	Injection molding, as a primary processing method, is particularly well suited for the mass-production of molded articles, because the conversion of the raw material into a finished product usually requires just a single operation. Little or no finishing is required, and even complicated geometries can be produced in a single operation.
ideal production process	It is an ideal production process with the proviso, that large batches are produced, because the injection molding tool is usually made for a single article only.
expensive molds	It is typical within the context of primary processing technology, that each mold is unique. Molds are therefore very expensive in comparison to most forming tools and dies used in metals fabrication, because they are not universally employable.

production process	The process for molding thermoplastics proceeds as follows: • The material is fed into the hopper on the machine. • Within the heated cylinder, the material is conveyed, melted, and mixed thoroughly by the rotating screw. • The molten molding compound (melt) is then injected into the mold under high pressure. • The melt cools within the heat-balanced mold and thus gains the inherent stability needed for its removal. • The article is now removed from the mold, and a new injection molding cycle can begin.
high degree of accuracy	Parts produced by injection molding display a very high degree of dimensional accuracy- for example, to 1/100mm (4×10^{-4} in). Even greater accuracy is possible in special applications.
CD	With the Compact Disk, information is stored in minute pits formed in the surface. These pits, produced as direct reproductions by the injection molding process, are only a few microns wide and deep.
Injection Molding -The Injection Molding Machine and Mold	
main components	• The injection molding machine • The mold
injection molding machine	The injection molding machine is in turn divided into the following: • Plasticating (plastification) unit and the injection unit • Clamping unit • Controls (hydraulics, electrical system)
mold	Different molds are needed for different injection-molded articles. It is therefore necessary to replace the entire mold in order to produce a different part from the one currently being made.
profitable production	Production of certain articles (e.g., household appliances, certain automotive subassemblies, CDs) would not be profitable at all without the means, of producing them from plastics by injection molding.
special features	When articles hitherto produced from classic materials (such as wood or metal) are to be made by the injection molding process, it is advisable, to give serious consideration to the special properties of plastics materials, as well as the more salient points of injection molding as a production method. This plastics-oriented procedure requires an understanding of the basic principles of the manufacturing and production processes involved, and also of the plastics material's behaviour. The book provides a comprehensive overview of the principles involved in injection molding.
CD	For that purpose, we follow a modern plastics article (a Compact Disk) from the starting material to the form, in which it will ultimately be used. The possibilities for recycling will also be explained. As a high-tech product, the CD is particularly well suited to serve as an example of modern plastics processing and injection molding technology. The diagram shows a CD and its dimensions.



Aside from viscosity, other factors also influence the processability of plastics in the injection molding process. The summary table below shows some of the types of plastics used in injection molding, as well as the characteristic material properties which are important in processing (e.g., shrinkage in processing, flowability, and processing temperature range).

Chemical name composition	ISO 1043 DIN 7728	Density [g/cm^3]	Processing temperature [°]	Flowability g = good m = medium p = poor	Shrinkage in processing [%] r = glass-fiber reinforced
Polystyrene	PS	1.05	180–280	g	0.3–0.8
Styrene-butadiene copolymers	SB	1.05	180–280	g	0.4–0.7
Styrene-acrylonitrile compolymers	SAN	1.07	200-260	m	0.4-0.7; 0.1–0.3r
Acrylonitrile-butadiene-styrene copolymers	ABS	1.08–1.12	210–270	m p	0.4–0.7 0.2–0.4r
Polyethylene	PE	0.91–0.97	180–270 240–300	g m p	1.2–2.8; 1.2–2.5
Polymethyl methacrylate	PMMA	1.18	170–240	m	0.3–0.7
Polyamide	PA	1.04–1.15	230–290	g	0.7–2.0; 0.2–0.8r
Cellulose acetate	CA	1.31	180–230	g	0.4–0.7
Polycarbonate	PC	1.20	280–320	p	0.6–0.8; 0.2–0.5r
Polyvinyl chloride, rigid (unplasticized)	PVC	1.38	190–210	p	0.4–0.7
Polyoxymethylene	POM	1.41	180–230	m	1.8–3.0; 0.2–0.6r
Polypropylene	PP	0.91	240–300	m p	0.5–1.2r

It can be seen from the table that the range of processing temperatures is very narrow for some thermoplastics but very broad for others. For example, PVCU (unplasticized or rigid PVC) can only be processed within a very narrow temperature range (190-210°C), while POM can be processed between 180 and 230°C.

The subsequent Table shows the material properties of PC, from which CDs are produced, as well as the setting parameters, which were used for programming the injection molding machine employed.

Material properties
Solid, rigid, impact resistant up to −100°C, (−148°F), high heat resistance, crystal clear, non-toxic.
Resistant to
Oil, gasoline, diluted acids, alcohol, waxes, fats, simple soaps
Not resistant to
Strong acids, alkali solutions, benzene, amines, ammonia, some solvent components.
Material characteristics
Flame retardant, extinguishes away from flame, burns brightly, produces soot, chars, forms blisters, smells of phenol.
Cylinder temperature

Heating zone 1	230–260°C
Heating zone 2	250-300°C
Heating zone 3	260–320°C
Heating zone 4	260–320°C
Nozzle zone	280–330°C

Injection pressure
Very high injection pressures (1300–1800 bar = 19.000–26.000 psi) are required, as the material is extremely viscous.
Holding pressure
Pressure usually amounts to about 40–60% of the injection pressure.
Back pressure
50–150 bar (725–2175 psi)
Injection speed
Subject to length of flowpath and wall-thickness. Fast injection for thin walls. Where good surface quality has been specified, injection should be a little slower.
Screw RPM
High screw torque required, therefore medium screw speeds should be applied.
Melt cushion
2–6 mm (0.08–0.24"), subject to feed volume.
Mold temperature
Not lower than 85°C (185°F). Mold filling and article quality improve with increasing temperature. High mold temperature increases cycle time only marginally, as the glass transition temperature is at 145°C (293°F).
Pre-drying
4–12 hours (high-speed drying oven 2–5 hours) at 100–120°C (212–248°F). Optimum elongation, hardness and notched impact strength are obtained at a moisture content below 0.02%.
Shrinkage
0.7–0.8%; 0.1–0.5% with PC-GF (glass filled).
Injection volume
15–85% of the respective cylinder volume.
Shutting the machine down
If production is stopped over night, purge the cylinder of material and keep heat on at 160–180°C (32–356°F).

It will be obvious by now, that many factors must be considered in order to produce high quality moldings. The processing values can also vary within wide ranges. The molding of CDs requires a PC of very low viscosity and a processing temperature range of 320-360°C. Low viscosity is needed, in order to enable the melt to reproduce the fine geometry of the pits on the information side of the CD with high precision. If this is not accomplished, data will be lost. Although CD-players have built-in error correction, this is capable of correcting lost information (non-existent or only partially formed pits) to a limited extent only.

Machine size:

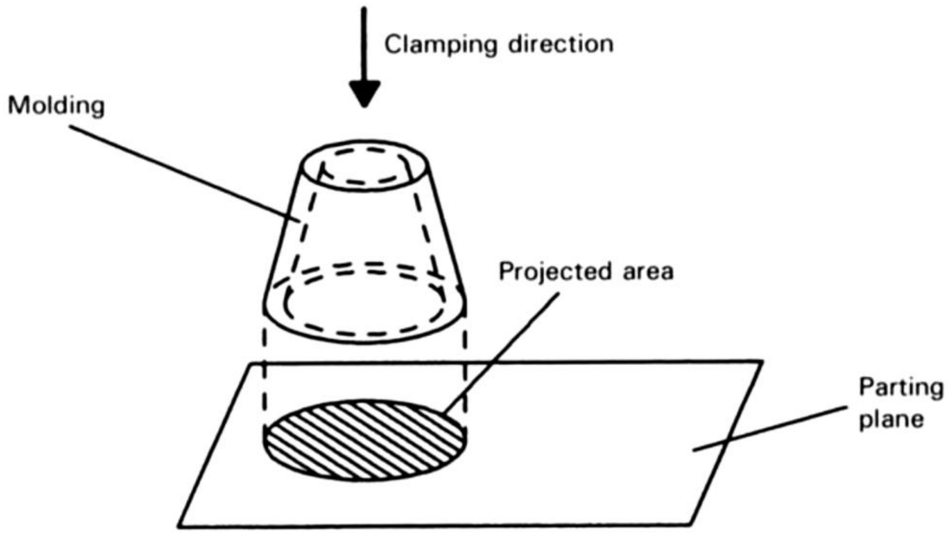
In principle, of course, it could be stated that the size of the machine must be chosen in accordance with the size of the molded article: the larger the molding, the larger the machine. But this isn't always true, especially where small molded parts are concerned. It is usually much more economical to manufacture many small moldings simultaneously on a large machine, than to manufacture just one article at a time on a small machine.

Article Weight:

The size of the molded part-especially in its relation to machine selection requires a closer examination. It should first be explained that 'size' is defined as volume. The heavier the article, the more molding compound must be provided by the plasticating and injection unit within a given period of time.

Projected Article Area:

Apart from a molding's volume, its dimensions must also be considered. The selection of a machine for the production of a given molding is primarily determined by the 'projected area' of that article - i.e., the area which projects in the clamping direction. Meaning of this concept is illustrated in the following figure:



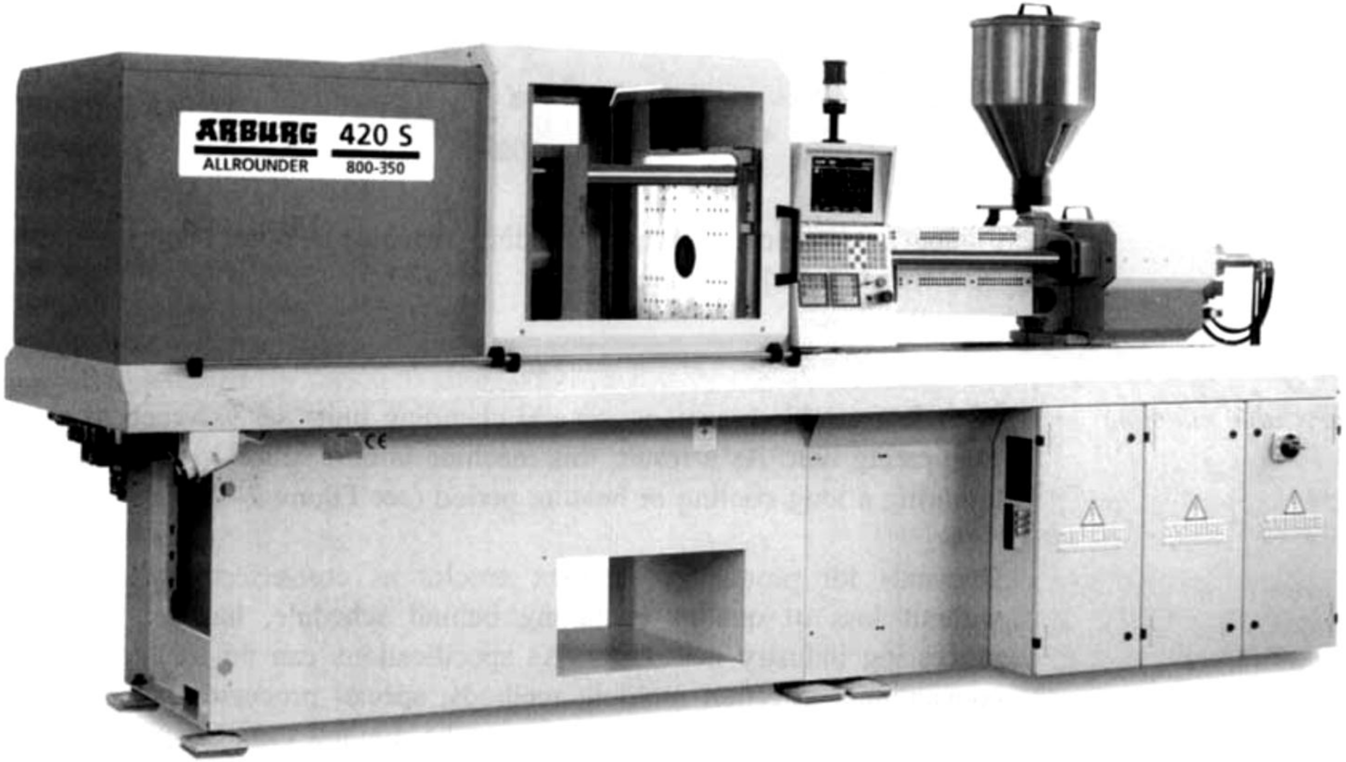
With the CD, the projected area equals the circular surface formed by the CD. Because diameter of the CD is 120mm (4.75 in), the projected area is 113 cm^2 (17.5 in^2).

With injection molding, the molding compound is injected into the mold under high pressure, which can be in excess of 2000 bar (29,000 psi) or 200 N/mm2 (1 bar = 10^5 N/m^2 = 10^5 Pa). By way of comparison, an automobile tire holds a pressure of approximately 2 bar (29 psi). The mold must be held shut against the injection pressure so that no molding compound escapes at the parting line between the mold halves (flash). This clamping force is provided by the clamping unit. Injection molding machines are classified into sizes which correspond to this clamping force (12 - 8000 t).

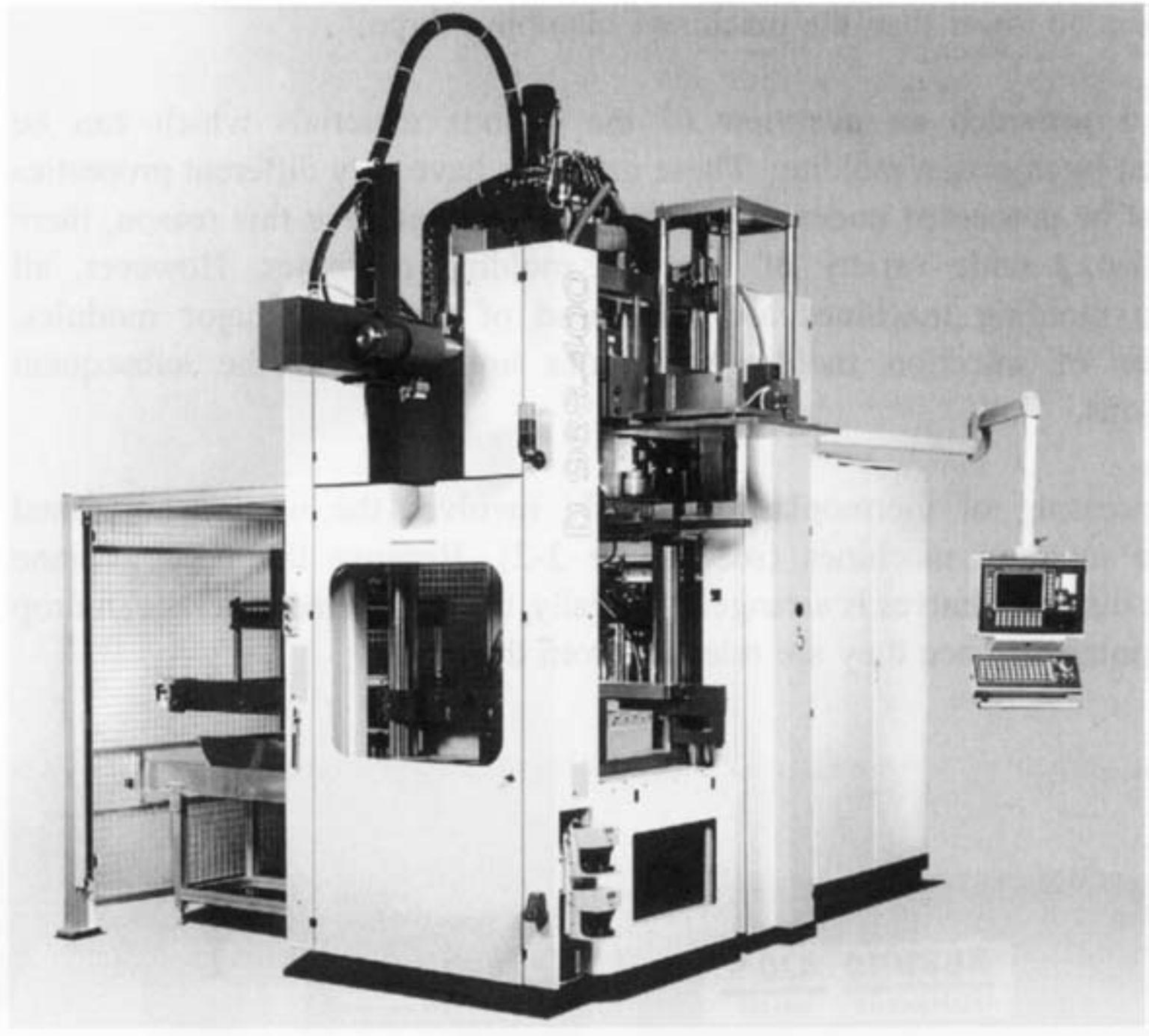
The force acting against the clamping force, thereby attempting to part the mold, is known as the mold parting force. It results from the pressure acting upon the melt, multiplied by the article's projected area, which lies in the clamping movement direction.

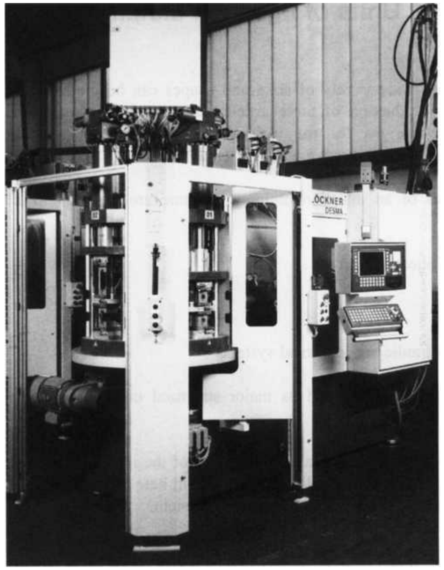
In order to achieve good quality moldings, i.e. without flash, the mold parting force must be lower than the machine's clamping force.

The processing of thermoplastics usually involves the use of horizontal injection molding machines. Because the parting plane between the mold halves is arranged vertically, the completed articles can drop into a container, once they are released from the mold.


ARBURG
420 S
ALLROUNDER
800-350

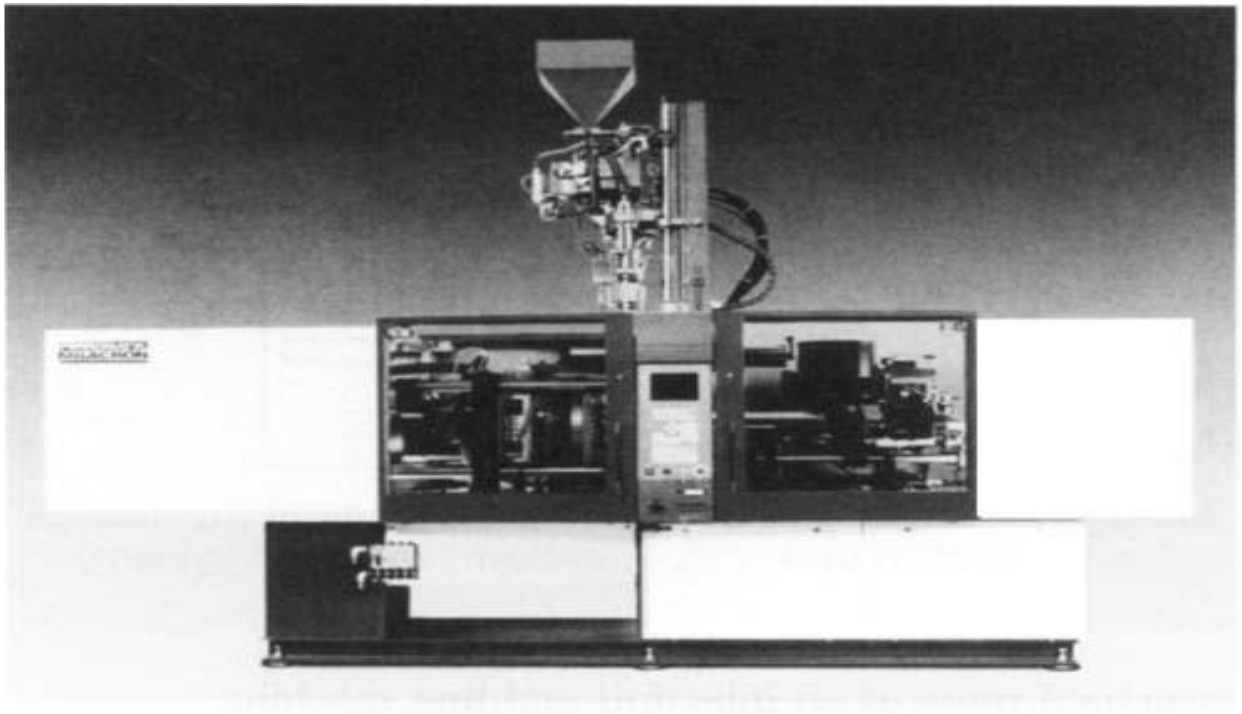
In the vertical machine, the parting plane between the mold halves runs horizontally. As a result, this machine is especially well suited to the production of insert moldings (e.g., electrical plugs) (see Figure 2-3). Most moldings made of elastomers are produced on vertical machines.





With rotary table machines, several clamping units are assigned to a single plasticating unit. As a result, this machine is best suited to molding articles requiring a long cooling or heating period (Figure on left).

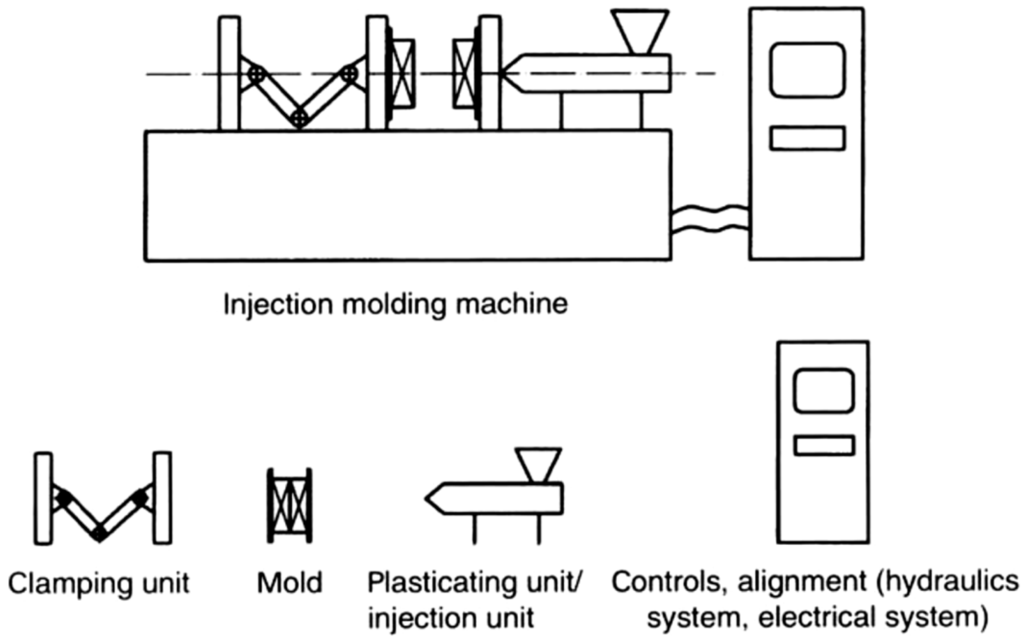
Demands for producing complex articles as cost-effectively as possible, without loss of quality or falling behind schedule, has set the plastics processing industry new tasks. As specifications can no longer be met by conventional injection molding methods, special processes -such as multicomponent injection molding - have to be applied (Figure below). With multi-component injection molding, at least two plasticating injection units are assigned to a single clamping unit. This method allows two differently colored plastics materials (automobile rear-lights) to be injected one over the other, forming a single molding.



Structural Units of Injection Molding Machines

Molded articles in a wide variety of sizes and shapes can be produced by injection molding. Production of these articles under optimum conditions requires alternative designs for the various sizes of injection molding machines, as well as their respective auxiliary equipment.

The major modules of an injection molding machine are common to all designs:



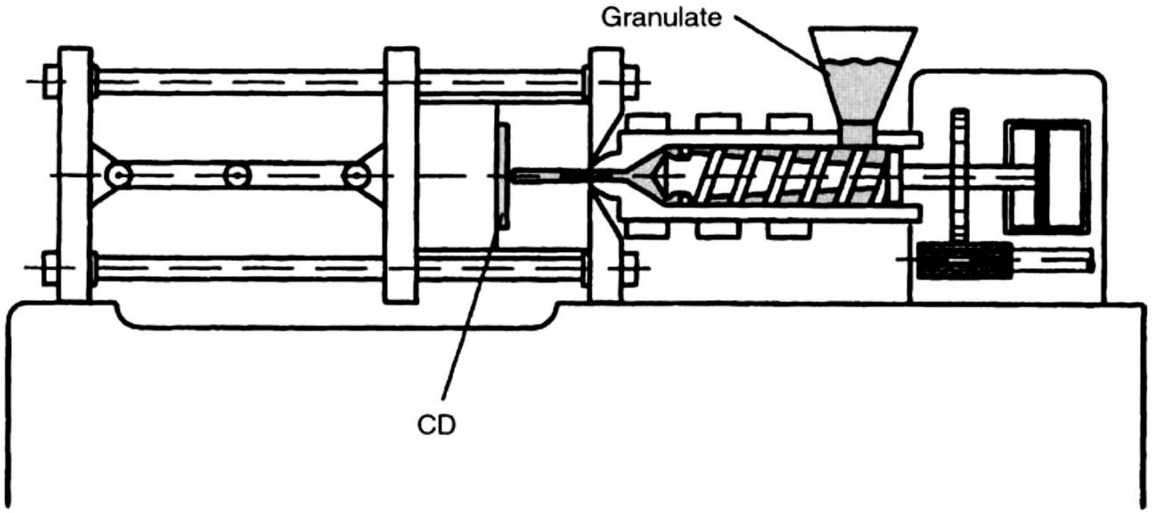
- Plasticating and injection unit
- Clamping unit
- Controls with hydraulic and electrical systems

An injection molding machine and its major structural units is shown in figure.

The mold is ordinarily not seen as a structural unit of the injection molding machine. However, in order to simplify matters, it will here be considered as part of the ‘‘overall’’ injection molding machine’s system.

The moldings to be produced determine the relative positions of these structural or modular units to each other, as well as their sizes. Various articles can be produced on a single injection molding machine, but each part requires its own (different) mold. The individual structural units of injection molding machines and their functions will now be described in greater detail. By way of an example, this description will refer to a machine used for molding CDs.

To understand the functions of individual modules, it is best to trace the path of the polymer through the machine from the raw resin (usually in granular form) to the finished product. The basic principle is demonstrated with the diagrammatic cross section of a CD-producing injection molding machine in Figure 2-7. The complete path of the material from hopper to mold is highlighted.



Production of the completed CD is much more complicated, of course. After it has been injection molded, it is given a metal coat by “sputtering”, which is necessary for reflecting the laser beam. The CD is subsequently subjected to quality checking and is then printed.

Controls:

The control and regulatory unit of the machine is usually housed in a separate control cabinet alongside the machine. In addition to the display instruments, the control cabinet also contains the electrical and electronic circuit elements and controls.

On older machines it is customary for the desired machine parameters to be set with limit switches located directly on the major modules or by push buttons on the control cabinet.

On modern injection molding machines, the keyboard and display screen have become the preferred devices for inputting and monitoring of set-values. With CNC-controlled machines, the heart of modem open-as well as closed-loop control is the microcomputer or a PC (Personal Computer). Apart from open loop and feedback control of the injection molding process sequences, these computers are also capable of monitoring and saving data.

Computer controls of this type employ interfaces, that enable them to exchange information for the production data acquisition (PDA), for instance, or quality data management (CAQ), handling devices or heat-balancing data. They can also enable hardcopy of production data to be printed.

Phases of an Injection Molding Cycle:

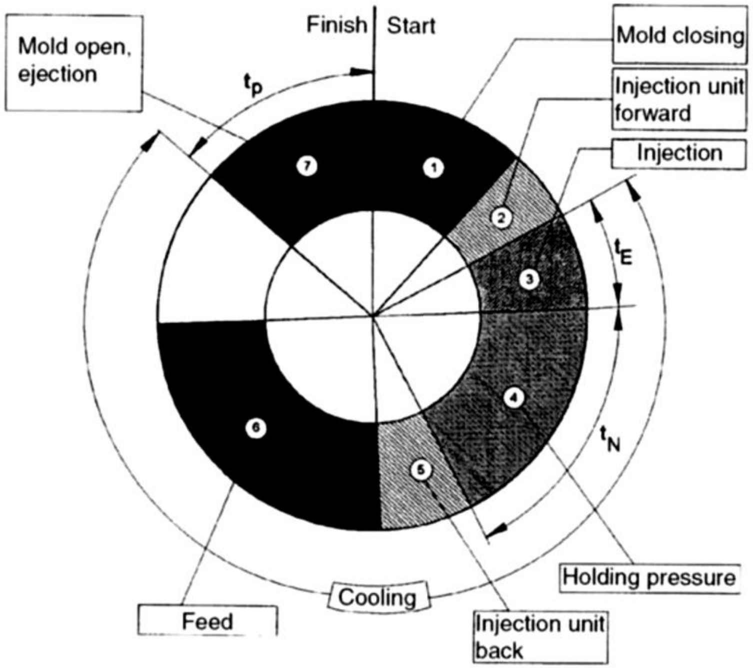
This lesson introduces the injection molding process in all of its phases (stages): injection phase, holding pressure phase, cooling phase, feed phase, and removal. The lesson also describes the machine motions associated with these process phases. In processing elastomers and thermosets, the cooling phase - as it applies to the processing of thermoplastics -is replaced by a heating phase.

To manufacture an injection-molded part, the machine’s structural units must work together in a practical manner. This cooperation between the units results in the injection molding process during which the molded part is formed.

The injection molding process consists of individual phases or stages which follow one another, overlapping to some extent, and are continuously repeated. We refer to a process of this type as a cycle and therefore speak of a repeating injection molding cycle. Nowadays, it is customary for the injection molding cycle to proceed automatically from phase to phase.

In most cases the cycle also repeats itself automatically. Only under certain conditions or for special molded parts may it be necessary for the machine to stop at the end of a cycle. After manual intervention by the machine operator, the machine is prepared for the next cycle and then restarted. This is done with molded elastomer parts, for example, which generally must be removed by hand.

The CD is produced by a fully automatic method, for example. In this case the machine operator intervenes only when problems arise.
The various times making-up an injection molding cycle are shown with the example of a CD:



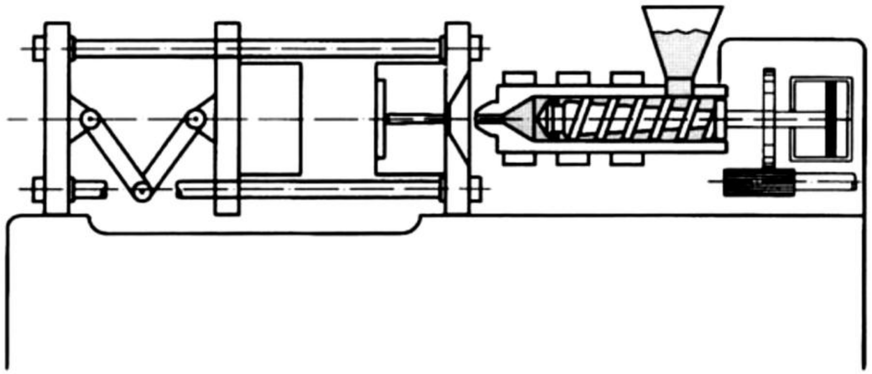
Phase	*Time [s]*
Mold closing	0.4
Injection	0.3
Holding pressure	0.3
Remaining cooling time	2.1
Mold opening	0.4
Handling (plus sprue punch-off)	0.4
Total cycle time	3.9

Due to its short cycle time, the CD is counted amongst fast cycling articles, similar to those produced for the packaging industry (e.g. cups). However, cycle times of other moldings may take from half- to several minutes. This depends on many influencing factors, such as article volume, material, gating design and demolding possibilities, amongst others.

The way the article is actually being molded cannot be observed directly. However, the machine's structural units can provide clues to the phase of the injection molding cycle the machine is currently executing.

Therefore, parallel to the description of the injection molding cycle phases, as seen from the material aspect, an explanation will also show, in which form the machine's structural units are involved.

To start molding production, all machine modules must be in their respective home position



Mold and Clamping Unit

The clamping unit is open. There is no molded part in the cavity of the mold. The ejectors are in the retracted position. The mold has been adjusted to the prescribed temperature.

Plasticating Unit

The screw and cylinder of the plasticating unit have been heated to the prescribed temperature. The screw is in the retracted position. Plasticated, molten material is present in the injection chamber in front of the screw. The nozzle has been closed off so that no material can escape.

Controls

If only one cycle is to be executed, the controls are in the semiautomatic mode. If a practically unlimited number of cycles are to be executed, the controls are in the fully automatic mode. The machine operator must start the process by pressing a button. Usually the process will start only if all machine components are in their respective starting conditions. If this is not so, the controls issue an appropriate error message or automatically restore the components to their starting conditions.

Hydraulic- and Electrical Systems

Of course, one precondition for the start of production is that the hydraulic and electrical systems of the machine must be switched on. Furthermore, the machine’s hydraulic oil must be up to the set operating temperature.

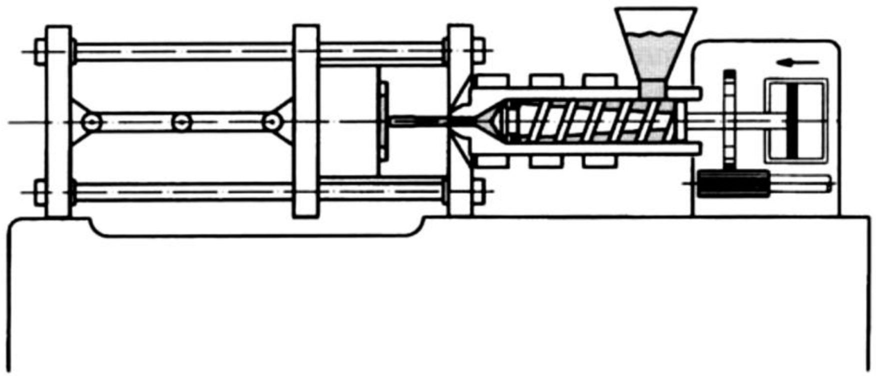
The material, i.e. the molding compound, is present in the screw's antechamber as thoroughly mixed melt. In processing conventional thermoplastics (PS, PVC, PE), the material is at approximately 200-300°C. The material, from which CDs are produced, is heated to approximately 330°C. The consistency of the plastics melt is roughly comparable to that of honey.

Once the machine operator issues the starting signal, the injection molding cycle begins with the closing of the mold.

Injection Phase

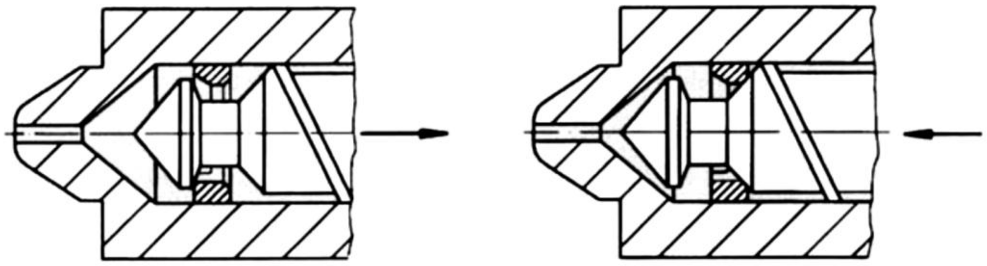
Mold and Clamping Unit

The clamping unit moves the two halves of the mold together. A clamping force is built up, thus locking the mold tightly.



Plasticating Unit

The plasticating unit moves up to the mold's sprue bush. The nozzle is opened, and the material located in the screw's ante-chamber is injected into the mold by the forward movement of the screw. As soon as the screw moves forward, pressure is exerted upon the non-return valve (check-ring valve) on the screw-tip by the material in the ante-chamber. As a result, the check ring of the non-return valve is pushed back onto its seat, thus stopping any melt escaping rearward over the screw flights. The screw now functions as a plunger during the injection process (figure below).



Controls

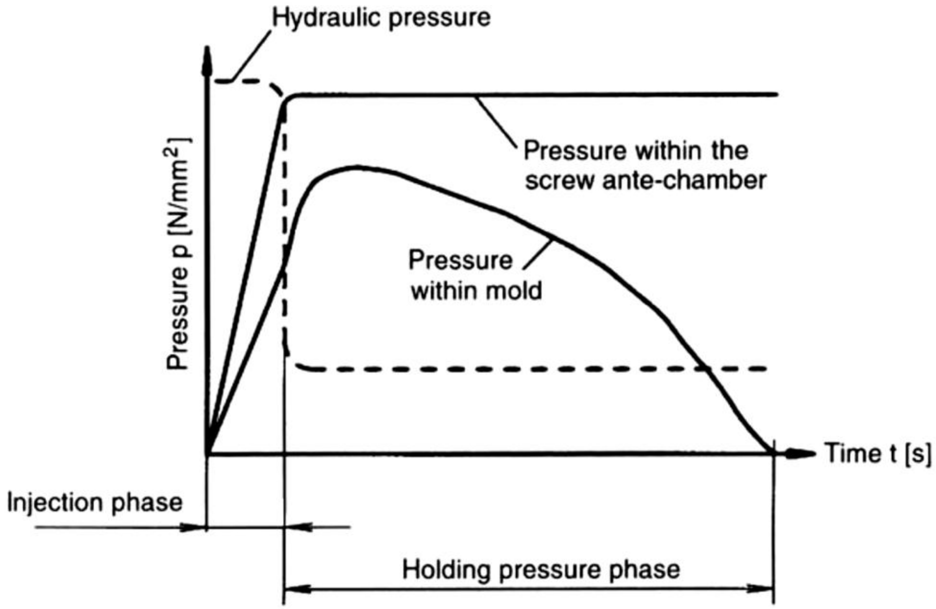
The controls must ensure that the structural unit movements are coordinated, while proceeding at the intended speeds and pressures. This places high demands on the precision of the controls.

Hydraulics

The hydraulic system must exert its highest power-output during the injection phase. Besides maintaining the clamping force, the hydraulic system must also be able to inject the plastics melt into the cavity at high, but precise, speed. To accomplish this, the hydraulic system must overcome the resistance offered by nozzle and mold. At the start of the injection process, the molten, homogenized material is poised in the injection chamber. The nozzle is closed, so that no material can escape. As soon as the plasticating unit has been moved against the mold's sprue bush, the nozzle can be opened to allow the melt free passage into the mold. At the same time, the hydraulic system exerts pressure on the screw, which moves in an axial direction, i.e. forward towards the nozzle. The material is thus forced out of the screw's ante-chamber and pushed into the mold cavity. The fluid, molten material must re-solidify within that cavity, so that the finished article can be removed later. Therefore, molds employed for thermoplastics are cooled or heat-balanced, in order to dissipate the heat introduced into the material during the melting process, thus allowing it to solidify.

As soon as the melt contacts the mold during the injection operation, it begins to cool and solid. Therefore, injection must occur quickly so that the cavity is filled while the compound is still fluid. This requires very high pressure, because the melt is merely viscous, despite the high temperatures used. The melt flow must overcome the resistance offered by the nozzle, sprue, and cavity, as well as some other obstacles, such as wall friction. The pressure in front of the screw may therefore exceed 2000 bar (29,000 psi) in the injection operation. The resistance in the nozzle, sprue, and cavity causes this injection pressure to decrease gradually in the direction of flow. Despite this, high pressures also occur within the mold. The clamping unit must be capable of holding the mold tightly shut against these pressures.

Figure below shows the pressure-curve inside the mold, in front of the screw, and in the machine's hydraulic system. The pressure inside the mold reaches its maximum value, when sufficient melt has been injected to completely fill all cavities.



The pressure in the hydraulic system is actually much lower than that shown in above Figure. The reason is, that this pressure is intensified to a higher value by the hydraulic ram's projected area. The hydraulic pressure acting on the hydraulic ram's large projected area transmits a great amount of force to the screw's "ram" tip. This force produces the high pressure within the injection chamber. The most critical point of the injection phase has now been reached. Most of the molding compound is still in a fluid state, so almost all of the pressure applied by the screw can be transmitted to the mold. If the injection pressure were maintained beyond this point, the resulting pressure within the mold could be great enough to overcome the clamping force. The mold would be forced apart in the parting plane, allowing melt to escape from the cavity.

This can have serious consequences. Flash forms on the molding, which will require finishing work, or the article may even have to be rejected. The consequences for the mold or the machine can be considerably more critical. The high forces applied can result in serious damage to mold or clamping unit.

It is therefore critical, that the injection pressure is switched off at the right moment. If this occurs too soon, it will result in the production of incompletely filled parts. Change-over to holding pressure asks for particularly high precision of the machine's control and hydraulic systems.

Holding Pressure Phase

As soon as the plastics melt fills the mold, it begins to cool. This cooling process begins at the mold wall and proceeds toward the center. For a certain period, the melt remains fluid inside the molding. As it cools, the molding material decreases in volume; in other words, it 'shrinks.' If the pressure were completely switched off after the injection phase, the molding would detach itself from the wall as it cools. There would no longer be any control over the molding's dimensions. It is easy to imagine the consequences in the example of the CD: the surface would become uneven, the scanning by laser would become less reliable-in short, the CD would be utterly useless.

This can be avoided. As long as the internal region of the molding remains in a fluid state, the pressure on the melt is maintained. Supplemental fresh material is forced into the mold in sufficient quantity to compensate for shrinkage. Of course, this works only as long as the sprue's inside remains soft enough. That is one reason, why the sprue should be positioned at the thickest point of the molding, if possible. Besides this, it should also be dimensioned accordingly. Holding pressure phase is the term for the phase in which just enough pressure is applied to compensate for shrinkage by the supplemental injection of material. This phase must last until the sprue has solidified-in other words, until no more melt can be supplementally forced into the molding. That event is known as 'sealing point'. In contrast to the injection phase, no flow resistance must be overcome in the holding pressure phase. Furthermore, practically no movement of material occurs in this phase. For these reasons, the holding pressure can generally be set to a lower level than the injection pressure. It is important to set the pressure to the proper level. If the holding pressure is too low, or if the holding pressure period is too short, this would result in the production of a defective molding.

It is important, to take a closer look at the position of the screw in the holding pressure phase. At the start of the holding pressure phase, the cavity has already been filled with most of the melt, that it is meant to receive. A small quantity is subsequently injected to compensate for shrinkage. But even at the end of the holding pressure phase, some residual material should still be in the injection chamber. This 'melt cushion' enables pressure to be transmitted between the screw and the cavity or sprue. This melt cushion is absorbed in the next shot.

Controls

During the holding pressure phase, the machine controls must ensure that the hydraulic pressure, which moves the screw, remains at the prescribed level. This will allow the supplemental injection of just enough material into the cavity to compensate for the shrinkage of the molded part. For this purpose, most machines offer the option of running a sequence of different stages of holding pressure levels. These stages are adapted to the geometry of the molded part.

Hydraulics

The hydraulic pressure is at a lower level during the holding pressure phase than the injection phase. The change-over from injection phase to holding pressure phase is critical, as far as the hydraulic system is concerned. The 'injection' mode is characterized by high screw speeds and high pressure, while the 'holding pressure' mode is characterized by a very low screw speed and a relatively low hydraulic pressure. The transition from the former mode to the latter must be performed with extreme precision and within the shortest possible time. This demands high precision of the switching operations. The injection and holding pressure phases are followed by two other phases,

which proceed concurrently.

Cooling Phase

The material is now in the cavity of the mold. It has reached the cavity in a flowable state and must now solidify under the influence of the relatively low mold temperature. This will allow the finished molded part to be removed. The solidification of the molded part must occur under controlled conditions so that no undesirable stresses develop within the molded part. These stresses would warp the molded part.

Feed Phase

The sprue on the molded part has solidified, thus preventing any further injection of supplemental molding compound. The plasticating unit can thus fulfill its other tasks. New material can be prepared in readiness for the next cycle.

Cooling Phase

For the material within the mold cavity, the holding pressure phase is concluded as soon as the sprue solidifies-in other words, as soon as it is 'sealed.' From this point on, no more material can enter the cavity. During the injection and holding pressure phases, the material in the cavity has already begun to cool against the relatively cold mold wall. The outer layers have solidified very quickly. The cooling time therefore starts as early as injection. Cooling takes longer in the middle of the molded part. The surplus heat of melt remaining there must be dissipated through the outer layers to the mold wall. Now it becomes apparent that plastics are poor conductors of heat. The thermal conductivity of plastics is approximately 100 times poorer than that of steel. Heat transfer can be effectively defined with the help of mathematical equations. This makes it possible to perform advance calculations of the cooling time, during which the molded part must remain in the mold until it is sufficiently cooled. The cooling time also depends on for how long a period it is intended to cool the article within the mold. It is not necessary, to wait until the entire molding has cooled to mold temperature. It suffices, for the outer part of the molding to cool just enough, so that it can be removed from the mold in stable condition. It would also be ill-advised to allow the part to cool within the mold for longer than absolutely necessary. The reason is that the machine is essentially in a waiting mode during the cooling period and is therefore unproductive.

The choice of the proper cooling time is also especially important from the profitability aspect. Apart from the complicated equations for defining the cooling process - as applied in computer simulations of injection molding - there are also simple equations which make it possible to calculate cooling times with a pocket calculator or by hand.

Cooling Time Equation

The cooling time equation has been derived at as a simple approximation for defining heat-transfer within the molding during the cooling process in the injection molding tool:

$$t_c = \frac{s^2}{\pi^2 \times a_{eff}} \times \ln\left(\frac{4}{\pi} \times \frac{T_m - T_w}{T_E - T_w}\right)$$

t_c[s] = cooling time to be calculated

s[mm] = article thickness

T_m[K] = melt temperature at the start of the injection process

T_w [K] = mold temperature

T_E [K] = demolding temperature (assumed temperature at the molding’s center, at which it is to be removed)

a_{eff} [mm^2/s] = effective temperature conductivity (the molding compound’s physical characteristics, which can be found in Tables, subject to the mold wall temperature)

The following equation can be employed for a rough calculation of the cooling time:

$t_c = 2s^2$

t_c[s] = cooling time

s[mm] = the article’s wall thickness

The article’s largest wall thickness is decisive, as it determines the cycle time.

According to this formula, a CD with a wall thickness of 1.14 mm (0.045 in) requires a cooling time of approximately 2.6 seconds. (For wall thickness in inches, the formula for cooling time is CD = 2000 s^2.)

Mold and Clamping Unit

The status of mold and clamping unit during the holding pressure phase is identical with the one of the cooling phase.

Plasticating Unit

During the cooling period, material is prepared in the plasticating unit for the next shot. A detailed description of the events which take place in the plasticating unit during this phase is given in the section titled ‘feed phase.’

Control and Hydraulic Systems

Because the cooling phase represents a waiting phase for the machine, no actions need to be taken as far as hydraulics and controls are concerned during this phase. The events which take place during the concurrent feed phase are described in the ‘feed phase’ section.

Feed Phase

During the feed period- following the completion of the injection and holding pressure phases -material for a new shot must be prepared and provided in the proper quantity. The material is ‘fed’ or ‘metered.’

To this end, the material in the hopper above the plasticating unit is drawn in by the rotating screw and conveyed along the screw flights in the direction of the nozzle. As it moves toward the nozzle, the material is exposed to many different stresses. Heat is transmitted to the material from the cylinder wall of the plasticating unit. This transfer of heat is called thermal conduction.

The material is sheared by the rotation of the screw and further warmed by the resulting frictional heat. This effect is intensified by the fact that the height of the screw flights decreases in the direction of the nozzle. The material is thus being compressed increasingly. It is simultaneously mixed (homogenized) in a thorough manner. The pressure conditions in the space between the screw and the cylinder wall cause trapped air to be conveyed in the direction of the feed zone.

The intense compression and mixing of the material is desirable for ensuring that its properties are as uniform as possible. By the time it reaches the tip of the screw, the material has become molten. It accumulates in front of the screw in the ante-chamber. As the screw can be moved in an axial direction, it yields to the pressure of the accumulating material and moves backward. In order to improve homogenization, this movement is restricted by adjustable resistance, known as back-pressure.

In most cases, more energy is introduced into the material by friction than by the hot cylinder wall. Ultimately, this energy must be produced by the drive motor. Therefore, the amount of energy introduced is especially dependent on the screw speed and back pressure setting. The screw speed influences the time required to prepare the material.

When the settings for the process are selected, it is important to make sure, that the plasticating time does not exceed the cooling time. The reason is, that the plasticating time can vary as a result of variations in material characteristics. If the plasticating time were longer than the cooling time, these variations would directly affect the cycle time, possibly causing the quality of the molding to vary as well. The following rule therefore applies: The plasticating time must not be allowed to determine the cycle time.

Furthermore, an optimum cooling time offers the advantage of greater profitability, since it allows more moldings to be produced, due to time-saving.

The molding's cooling phase m s concurrently with the feed phase. As soon as the feed phase has ended, the material is available in the injection chamber for the next cycle. During the waiting period- while waiting for completion of the molding's cooling phase -a heat exchange occurs between the melt in the screw's ante-chamber and the cylinder wall. It is important to ensure, that during this waiting period the melt neither cools excessively nor absorbs too much heat and starts to decompose.

Mold and Clamping Unit

The mold and clamping unit are not involved in the plasticating operation.

Plasticating Unit

The preparation of new material begins immediately after the completion of the holding pressure phase. If a shut-off nozzle is used, it will close as soon as the holding pressure phase has timed-out. In this case the plasticating unit will be retracted from the mold to avoid excessive heat-transfer from the hot nozzle to the cooler mold.

If no shut-off nozzle is used, the plasticating unit cannot be retracted until the feed phase has ended. Otherwise, the molding compound would escape from the nozzle prematurely.

During the plasticating process, the screw is rotated by a hydraulic motor. The material descends from the hopper and enters the feed zone. The rotation of the screw then conveys the material toward the screw tip and through the open non-return valve. The screw is forced backward by the material accumulating in the injection chamber (ante-chamber) in front of the screw tip. As soon as the introduced melt has pushed the screw back to trigger the adjustable feed stroke limit switch, screw rotation is stopped. During the feed phase, the plasticating unit has readied the material for the next cycle. It has thus completed its task and is now in a waiting position.

Mold Layout

The dimensioning of the mold (phase I1 of the mold design) essentially includes the rheological, mechanical, and thermal mold layout. These aspects of the layout can be further divided into several steps, each with its own special emphasis:

Rheological:
- Determining the filling pattern
- Rheological calculation of the filling- and holding-pressure phase
- Layout of the runner system

Thermal:
- Cycle time calculation
- Energy balance of the mold overall
- Heating/cooling system layout

Mechanical:
- Kinematics
- Rigidity analysis

The quantitative layout of the cavity region and gating system requires primarily rheological expertise - in other words, knowledge of the flow characteristics of polymer melts.

The dimensioning of the mold temperature control system requires corresponding knowledge of the heat transfer subject. Mechanical and kinematic expertise are required in the dimensioning of the mold structure and the layout of the article removal system.

Rheological Mold Layout

The filling characteristics of the cavities are determined in the rheological mold layout. The filling phase and holding pressure phase determine the properties of the molded part. The rheological mold layout can include several steps:

- Establishing the filling pattern (qualitative)
- Rheological calculation of the filling- and holding-pressure phase (quantitative, e.g. pressures and temperatures) and
- Layout of the runner system

Establishing the filling pattern, which can also be determined graphically, makes it possible to confirm the positions of
- Weld-lines (which develop at the conflux of two different melt-sections)
- Air entrapments (which develop when air is trapped by the melt)
- Suitable sprue positions.

Figure 8-2 shows the establishing of the filling pattern for two simple, plate-like moldings. This shows the positions reached by the flow fronts at different times. Each plate is filled from the gate (feed point). Emanating from a single point by laminar flow, the flow-fronts spread like waves into the mold cavity, which has been empty until now. This results in concentric circles around the feed point. If the cross section is altered, as shown on the right side of Figure 8-2, the filling pattern will also change. For rectangular cross sections, these relationships can be calculated approximately by the following formula:

$$\frac{\Delta l_1}{\Delta l_2} = \frac{s_1}{s_2}$$

where A1 [mm] stands for the flow front progress and s [mm] for the article's wall thickness.

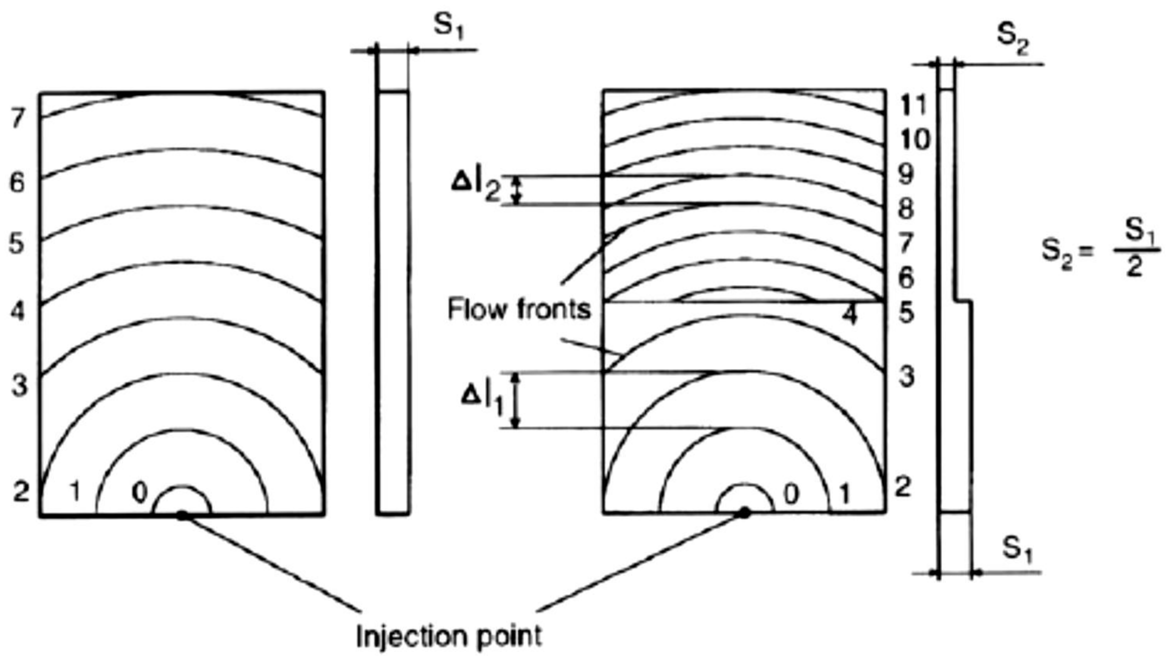


Figure 8-2 Establishing filling patterns for two simple, plate-like moldings

For example, if the height of the cross section is reduced by half, the distance from one flow front to the next will also be cut in half. This means that filling the right plate will take longer than filling the left one.

The following example illustrates the filling simulation. When molding a toy locomotive profile air is trapped at the far side, opposite the gate (Figure 8-3 left). This can also be predicted by simulation (Figure 8-3 right).

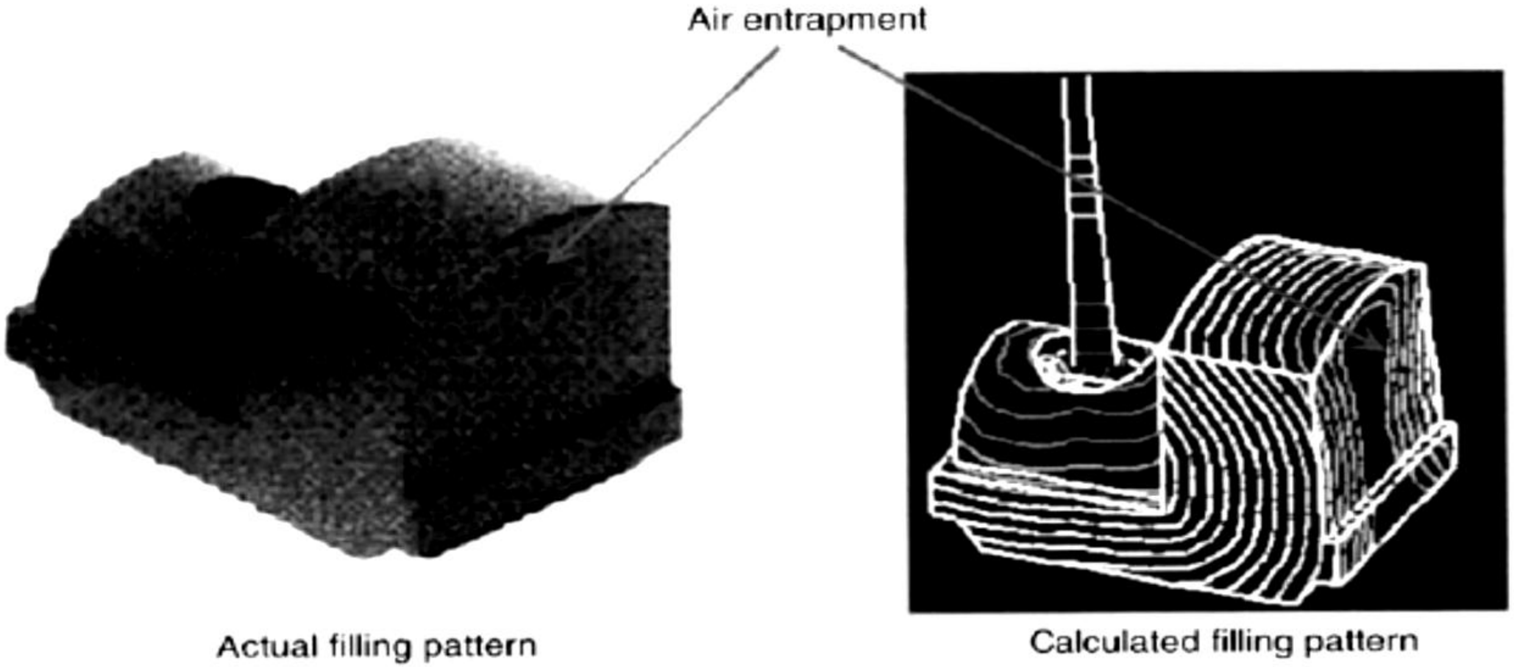
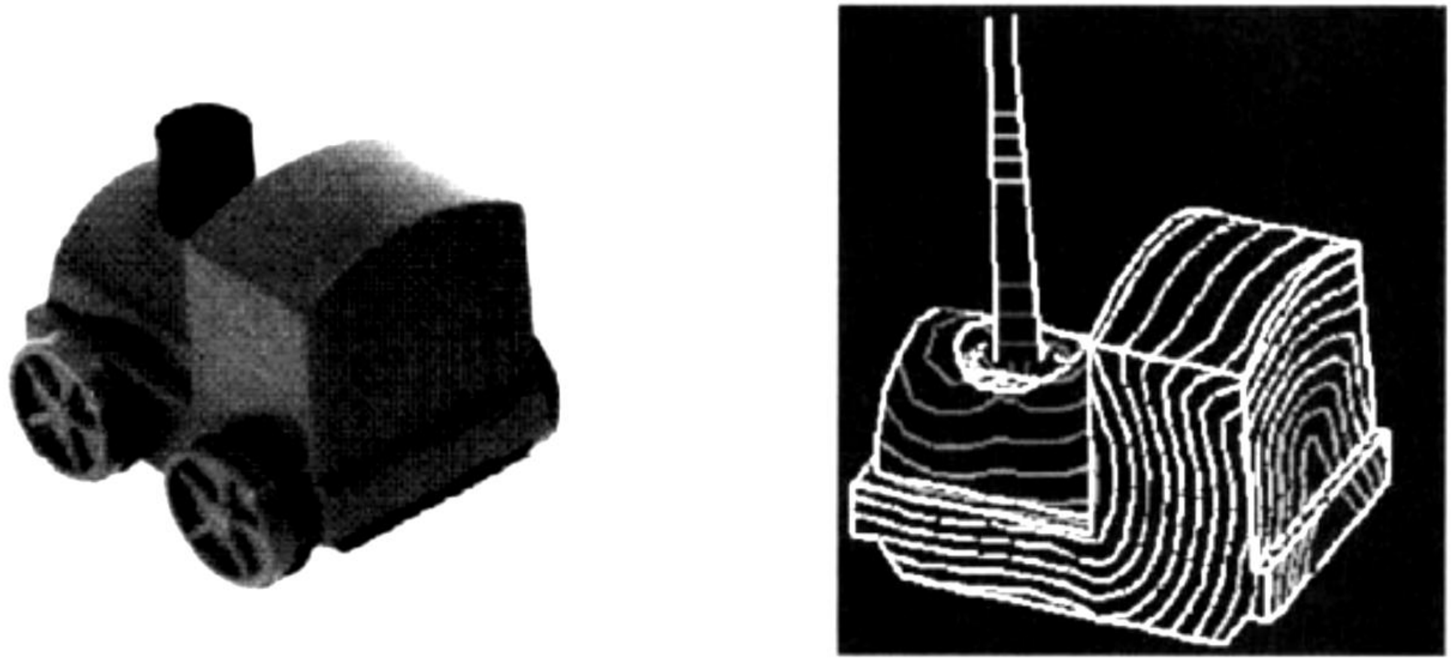


Figure 8-3 Filling pattern of toy locomotive

The profile of the flow front can be optimized in such a way by varying the wall thicknesses, that air entrapment is eliminated. Figure 8-4 shows the flow front profile, as established by computerized filling simulation, based on a filling pattern method. This could also be produced manually, with a pair of compasses and a ruler.



Perfect locomotive   Optimized filling pattern

Figure 8-4 Flow front optimized by simulation

Even the positions of weld-seams, which develop when two flow fronts meet, can be determined with the aid of simulation.

This filling pattern is generally created independently of material properties and process parameters. In other words, it is partly established by applying simple graphic rules. The actual rheological layout of the mold is based on the following specifications: material and processing data, such as the compound's melt density, the injection rate, the injection temperature, and the material's rheological properties. These, for instance, enable statements to be made, regarding:

Pressure requirements for mold filling:

- Melt temperatures
- Speeds/velocities
- Shrinkage characteristics

The pressure requirement for filling the mold cavity determines not only the injection molding machine model to be chosen, but also the size of the mold construction elements.

Like the filling phase, the cooling phase is also critically important to the quality of the molded part. The injected part is cooled within the injection mold for the length of time needed for the part to become sufficiently solid and capable of being removed.

The mold temperature control system must therefore be laid out in a manner which allows the heat of the molded part to dissipate uniformly and within the shortest possible time. Aside from the quality of the molded part, therefore, profitability is also strongly affected, because of the effect on the cycle time.

The shorter the cooling time, the shorter the cycle time will be. The thermal mold layout also includes several stages:

- Calculation of cycle time
- Energy balance of the overall mold
- Layout of the heat-balancing system

With knowledge of the material temperature, wall temperature, ambient temperature, plus the specification of the article removal temperature, it becomes possible to analyze the energy balance of the overall mold. Decisions on whether and how to provide the mold with thermal insulation are made at this stage of the layout. The performance of the temperature control system is also established at this stage. Figure 8-5 shows the heat balancing of an injection molding tool.

The term heat balance space refers to the space considered for heat exchange phenomena. The heat flow emanating from the molded article enters the balance space. The following pass-out of the heat balance space: the heat flow dissipated by the heat-balancing medium, the convective- as well as the radiant heat-flow (both to the environment), and the thermal conductivity flow, which enters the platens.

The next step is the layout of the heat-balancing system. This step involves establishing the number of heat balancing circuits required, the distances between the cores for the heat-balancing medium, the distances between the cores and the cavity surface, and the temperature and throughput rates of the heat-balancing medium. The design of the heat-balancing system is precisely determined by this layout. The goal is the most uniform dissipation of heat from the cavity region which can possibly be achieved.

The optimal cycle time, which was described in the previous lesson, is calculated in the final stage. This maximizes the profitability of production. The cooling time amounts to 50-700/0 of the cycle time. It increases by the square of the article's wall-thickness. For this reason, wall thicknesses exceeding 6 mm (1 /4 in) are rarely chosen.

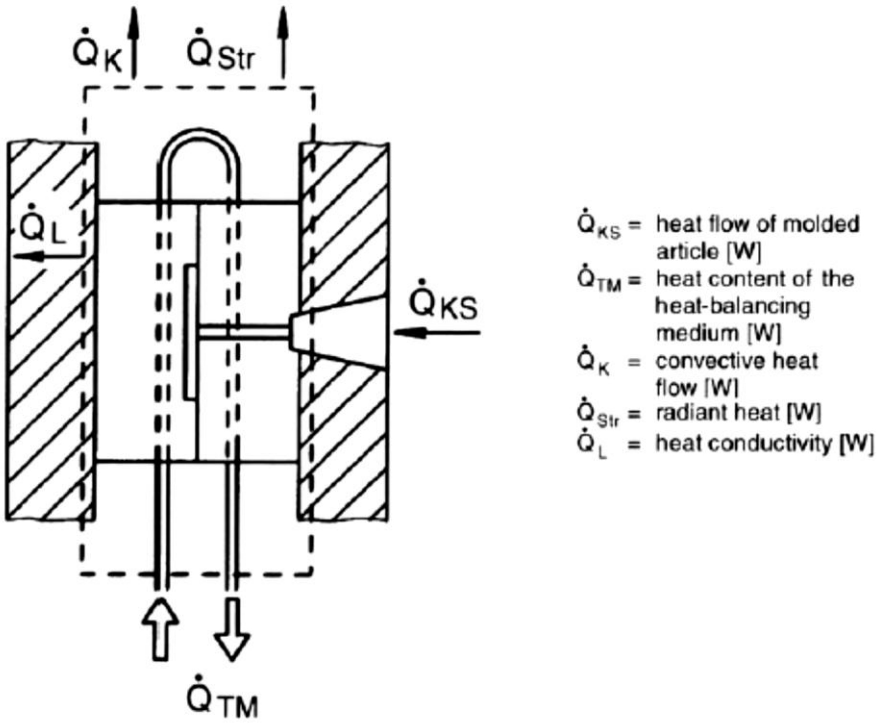


Figure 8-5 Heat balance of an injection molding tool

A rule of thumb formula for calculating cooling is given in greater detail in Lesson 7.5. The formula employs variables of the melt temperature, wall temperature, demolding temperature, as well as the plastic material's thermal conductivity.

Calculation of the CD's cooling time results in:

- The CD has a wall thickness of 1.14mm (0.045in) and is made of polycarbonate. It is processed at a material temperature of approximately T_M = 330°C. The mold wall temperature is T_W = 60°C and the thermal conductivity of the plastics material amounts to a_{eff} = 0.01 mm^2/s. The demolding temperature-measured at the center of the molding-is assumed to be about TE = 110°C.
- Calculation by cooling time formula results in a cooling time of T_E = 2.5 s

Current cycle times for the fully automatic production of CDs are given as 3.9 seconds, with the cooling time accounting for approximately 2.7s. But it is quite possible, to achieve even shorter cycle times for this process.

Mechanical Mold Layout

Injection molds are among the most heavily loaded devices in industry, as they are exposed to clamping forces of up to several thousand tons and internal mold pressures up to 2000 bar (29,000 psi). Because these molds are intended for the manufacture of molded parts of extremely high precision, it is necessary to consider the deformations undergone by the injection mold under these loads.

The mechanical mold layout is also produced in several stages. For example, factors related to kinematics and rigidity in the clamping direction are considered.

Because mold deformations are intended to occur in the linear-elastic range, an overlap between loads and deformations is permissible in principle. Linear-elastic means that the deformation changes linearly (i.e., along a straight line), as the force exerted upon a component increases. When the load is removed, deformation will return to zero. The component behaves like a spring. The modulus of elasticity is a measure of linearity for this response. The higher the modulus of elasticity, the less deformation will be experienced by a stressed component.

The individual parts of a mold basically behave like a spring. When a spring is subjected to a load, it is compressed. When the load is removed, the spring relaxes and returns to its starting condition.

Therefore, the mold deformations are calculated on the basis of a spring model. The deformation characteristics of the component being tested can be simulated by an appropriate combination of springs. An example of a simple mold and the corresponding spring model are shown in the schematic diagram in Figure 8-6. The five elements of the component are divided into five springs. The laws of elasticity for series and parallel combinations of springs are needed for the calculation.

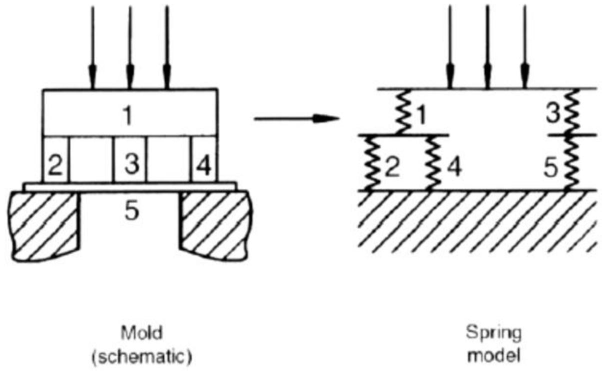


Figure 8-6 Spring-set model

One layout step is the consideration and dimensioning in the clamping direction. The criterion for this aspect of the layout is that platen deflection must not give rise to any prohibitively large gaps in the parting plane, which would allow melt to intrude (flashing). This flash would eventually result in the destruction of the mold. An additional step in the mechanical layout involves the consideration of components such as ejector pins and guidance systems. The forces which figure prominently in these considerations are inertial and frictional forces. These forces load not only the above-mentioned components but also the molded part. It is sometimes necessary to overcome a high degree of static friction, especially when the part is removed from the mold. This static function is frequently more likely to cause damage to the molding than to the ejector pins.

Time-consuming calculations are necessary for complicated mold geometries and stresses. These tasks are carried out by computer programs.

Figure 8-7 shows a section through a mold in its stressed and unstressed condition. This computer calculation clearly indicates deformations of 4.0 mm (0.15 in) (unstressed condition) to 4.1 mm (0.16 in) (stressed condition) in the cavity area. For easier understanding, the deformation in the stressed condition has been exaggerated-that is, the representation is not true to scale.

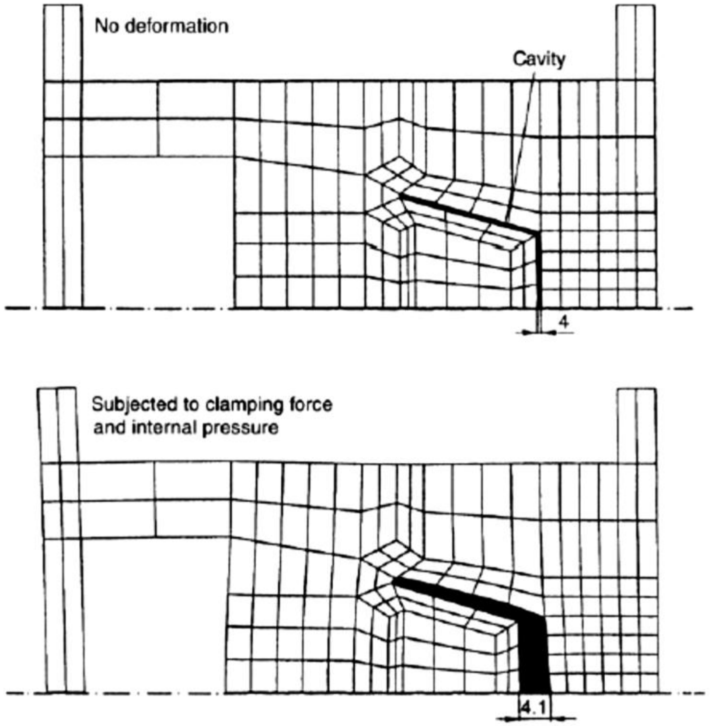


Figure 8-7 Simulation of deformation characteristics

Introduction to Extrusion:

During extrusion, a polymer melt is pumped through a shaping die and formed into a profile. This profile can be a plate, a film, a tube, or have any cross-sectional shape. Ramtype extruders were first built by J. Bramah in 1797 to extrude seamless lead pipes. The first ram-type extruders for rubber were built by Henry Bewley and Richard Brooman in 1845. In 1846, a patent for cable coating was filed for trans-gutta-percha and cis-hevea rubber and the first insulated wire was laid across the Hudson River for the Morse Telegraph Company in 1849. The first screw extruder was patented by Mathew Gray in 1879 for the purpose of wire coating. However, the screw pump can be attributed to Archimedes, and the actual invention of the screw extruder in polymer processing by A.G. DeWolfe of the United States dates to the early 1860s. The first extrusion of thermoplastic polymers was done at the Paul Troester Maschinenfabrik in Hannover, Germany in 1935.

Start Up

Startup refers to those procedures involved in getting a machine into full production. It is very important to have intelligent start up procedures, as adherence to such procedures will minimize dangers to the operator and damage to the equipment.

Check the Heating System

Before commencing operations, one should first check that the thermocouples are in their specified positions, of the correct type and are connected to the appropriate instruments in the control panel. If there is a thermoplastic material in the hopper, its feed gate should be closed. Make sure that the drive motor is off and that the speed is at the lowest setting possible. See that the cooling water is on and flowing at the correct rate through the hopper throat and the barrel cooling system. Turn off any cooling water to the screw. Turn on the heating system and set the temperature controllers to a very low value (for example, 50˚C). After this temperature is reached and held, by the control system, one can then begin heating up the machine for production to begin. The actual procedures may differ if the machine contains polymer or, if it is empty.

Warming Up an Empty Machine

Check the records or obtain experienced advice on what machine settings are needed for the job at hand. Turn the main power switches on. Program the heat input to avoid an overshoot (melt temperature over-ride or MTO) while heating up the extruder in a reasonably short time. This is usually accomplished by using temperature controllers fitted with a three term (PID) control. As it is asier to heat a barrel than to cool it down, it makes sense to approach the final operating temperatures slowly to minimize the risk of a temperature over-shoot (unless it is known that the system will not over-shoot). This is most easily done by setting the temperatures about 20˚C/30˚F below the running settings, during initial barrel heat-up. Once the system has stabilized at the preliminary settings then heating to the desired running temperatures is carried out. Such a procedure is necessary with some materials, such as plasticized polyvinyl chloride (UPVC), where an overshoot can cause serious degradation before processing commences. Once the machine is at the set temperatures it should be allowed to equilibrate before any material is introduced into the barrel. Keep this time as short as reasonably possible. Otherwise, residual material present in the screw flights may burn when heated in the presence of air.

Warming Up a Full Machine

When a full machine is being warmed up, it is important to ensure that it is heated in a way that avoids decomposition of the polymeric material. Decomposition can produce gases that, under pressure, can cause serious accidents by blowing hot material from the die. All temperatures should be set below the melting temperature of the particular material (for example, to 135˚C for LDPE). Allow the machine to reach and equilibrate at these temperatures. Next raise the temperature of the die to above the melting temperature of the resin. Then raise the temperature of the front zone and the rear zone to above the melting temperature. Finally, working towards the center, raise the temperatures of the other zones. Allow the machine to equilibrate at these temperatures for a short time before purging. Only proceed if the purged material looks satisfactory, i.e., sufficiently melted, but not excessively hot.

Barrel Temperature Settings

These are the temperatures set on the control instruments essential to reaching a desired melt temperature. Once an extruder is up and running, most of the heat input required for extrusion is mechanical heat supplied by the screw and drive system. The heaters are used only to warm up the machine and to “fine tune” the system during operation. One should remember that it is the melt temperature that is important, and any barrel temperatures quoted in the literature are only guidelines. When there is no experience with the processing of a particular grade of material, one should start with the lowest recommended settings. Unless the records show otherwise, use a flat temperature profile (each zone set at the same value). Recommended temperatures are 100˚C/200˚F above the glass transition temperature (T_g) for an amorphous thermoplastic material and 50˚C/70˚F above the melting temperature (T_m) of a crystalline material. One should always remember that the melt temperature is almost always higher than the highest barrel set-point temperature.

Equilibration

Once the machine is at the set temperatures, it should be allowed to equilibrate for about 20 minutes before material is introduced into the barrel. This time can be used to check that the die is clean and that all parts are operational. Review the production order for color and quantity and check that all necessary tools and equipment are in position. Check that ancillary equipment, such as the hopper or feed system, is clean and is functioning as required.

Initial Purging

Check the records to determine which screw is needed for the job at hand. Ensure that the correct screw is in the machine and that it is installed properly. Once the machine has equilibrated at the running temperatures, start the screw rotating slowly and then introduce some material by hand into the hopper. Do not fill up the screw throat, otherwise the material may not melt completely, and the un-melted granules may block the die and destroy any pressure transducers in the die and barrel. If everything appears satisfactory (for example, no melt frothing, spitting or motor overload) slowly increase the amount of material on the screw until it is covered with material. Then fill the hopper with material. Check the melt temperature with a melt probe and also check the general appearance of the melt. Proceed only if this purged material looks satisfactory, the melt temperature is as specified, and the motor amperage is not excessive.

Starting Up

Before starting up, a lead piece (produced in a previous run) or a piece of string is threaded through the cooling system and then through the haul off. The operator should wear suitable gloves. It is also useful to have an arrow drawn at the end of each roll that shows the direction of roll rotation and the path taken by the extrudate through the system. The haul off may then be moved to a convenient position in front of the die and the extruder run at a low speed. When the material is extruded from the die it is attached to the lead piece by tying or by melt adhesion. The operator steadily pulls the piece through the system. The nips are often left open so that any joints or irregularities may pass. This drawing, or pulling, requires skill and it is essential that the operator is not distracted as he is guiding the extrudate over obstructions, around hot rolls etc. Usually the extrudate is cooled as it is being drawn away, as this gives the product strength. Once the extrudate has passed through the haul off, the haul off drive is started and the speed adjusted before the nips are closed (save the lead piece for the next start up). Ensure that the haul off cooling system is fully operational and adjust its position to the running position relative to the die. Gradually increase both the screw speed and the haul off speed, providing that the machine operating parameters are within previously stated limits. Adjust the speeds to give approximately the correct dimensions and then adjust the die to produce the required dimensions. Any adjustments must be made slowly as this usually saves time.

Safety Considerations

One of the most dangerous times during processing is at start up. This is because material being heated in the machine may decompose and spit from the die. The operator is focused on getting the machine running satisfactorily and this involves close contact with machinery. So, great care should be taken at start up. In particular, no one should be allowed to stand in front of the die/nozzle and the hopper lid should be firmly in place, so that the screw cannot be seen (and therefore touched). No unauthorized person should be in the processing area.

Temperature Problems

If the use of a flat temperature profile causes:

- Premature melting and bridging of the material (resin) in the feed throat: gradually decrease the feed zone temperature
- High die pressure fluctuations: raise the feed zone temperature
- Melt temperature fluctuations: raise the transition zone temperature
- The barrel temperature to exceed a set point: slowly raise the set point temperature of that zone (raising the transition zone temperature can, however, reduce viscous heat generation and may cause incomplete melting)
- A loss of product gloss: raise the die exit temperature

Introduction to Blow Moulding

The basic process is common to all variations of the blow moulding method, which consists of three stages:

1. Melting and Plasticizing – This is accomplished with either extrusion and/or injection moulding machine to produce the melt.

2. Plastic Formation – Through head and die or in an injection mould.

3. Blowing and Moulding – An auxiliary compressor provides air pressure and a clamp unit, which closes over a split mould that is operated with a hydraulic system.

The first step involves the production of a hot tube, known as a parison, a term derived from the glass industry. This may be produced, as indicated, by one of two methods, extrusion or injection. In the injection case it is referred to as preform. The heated parison or preform is placed between two halves of the blowing mould, which closes and clamps around it. The heated tube is blown against the cavity wall and the molten plastic or resin takes the shape of the mould while being cooled. This is illustrated in Figure 1.2. After the cooling stage the part is ejected from the mould. In the case of an extruded part it is necessary to remove the flash (excess plastic around the part) for further finishing.

Drilling, labelling or printing may be required in both methods. Moulding for high volume production parts often uses robots.

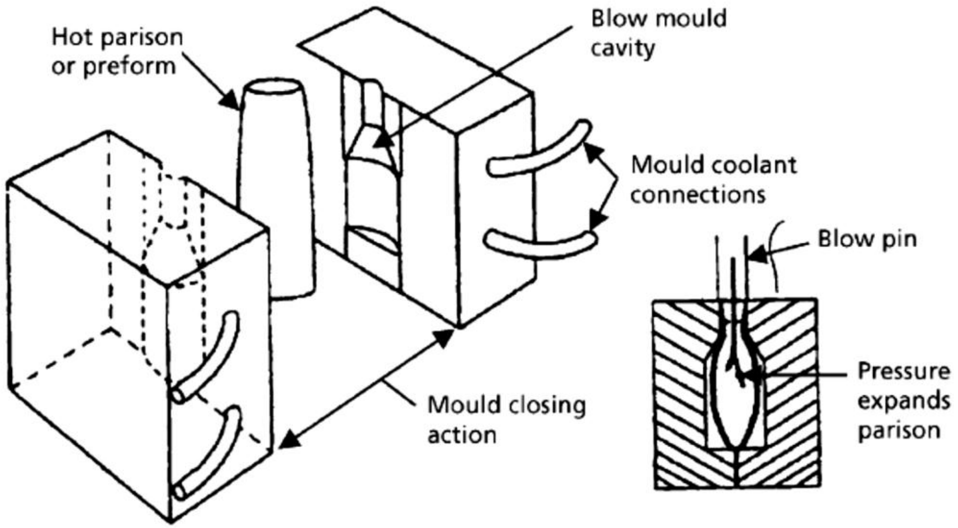


Figure 1.2 Basic blow moulding process

Start-Up Preparations of Blow Moulding Machines

An understanding of the settings is needed before starting up a blow moulding machine. Obtain advice from someone who is very familiar with the equipment, or better yet, consult the written procedures. A general procedure is:

- Turn on the main power switches and then select or set the temperatures.
- Ensure that the cooling water is on and check to see that it is flowing through the feed throat.
- Preheat the hydraulic oil to its correct operating temperature.

This may be done either by pumping the oil back into the tank or by using a preheater fitted for this purpose. Once the machine has reached the required temperature, it should be allowed to settle down before any material is introduced into the barrel. The settling-in (equilibration) time, sometimes called 'soak' time, is the time needed for the barrel, screw, breaker plate, and die or mould temperatures to stabilize close to the temperature set points. The equilibration or soak time will depend on the size and type of machine. It may take 20 minutes for a small machine and it may take several hours for a larger machine. This time should be used to prepare for the production run.

Other start-up steps include:

- Check the nozzle/die and moulds to see if they are clean and operational.
- Review the production order for colour, quantity, and other requirements.
- Check for necessary tools and equipment and be sure they are in place and working properly.
- Make sure that all auxiliary equipment is clean and operational, to include hopper loaders, conveyors, grinders, vacuum pumps, and leak testers.

Melt Temperature

Two methods are commonly used to measure melt temperature in a blow moulding machine:

- Extrusion or injection of the material onto a suitable surface, then measuring the temperature of the plastic mass with a thermocouple probe.
- Direct reading by a thermocouple that is placed in the barrel and is in direct contact with the melt.

When the temperature of the melt is measured with a probe, care should be taken during the measurement to ensure that the purging of hot plastic does not cause an accident. As has been mentioned previously, molten material will cause serious burns because it is very hot and it adheres to the skin and is very difficult to remove. Burns are a common injury in moulding operations, so long sleeves, gloves and face shields should be worn when handling hot material or where there is danger of being splashed with hot plastic melt, particularly during start-up or purging. As with other situations requiring personal protective equipment, the plant's requirements must be followed.

Warming up an Empty Machine

The machine's warm-up cycle should be programmed so that thermal overshoot does not occur, and heating times are kept reasonably short. Once the machine is at the set temperature, it should be allowed to equilibrate ('heat soak') before material is introduced into the barrel. It is advisable to keep this time as short as possible so that any resin left in the barrel after purging does not degrade. Check the machine for correct temperatures by briefly rotating (jogging or 'inching') the screw. If the screw requires excessively high motor currents or will not rotate, then allow the machine to equilibrate further. The set-up sheets should show the normal heat soak time. Before starting the machine, be sure that the set conditions are satisfactory by purging a few pounds of resin out of the die (or nozzle) at slow screw speeds. Check the melt temperature with a melt probe and also check the general appearance of the melt. It should be smooth and free of dark specks, streaks, bubbles, or other signs of degradation. If no material is delivered when the screw is turned, check to see that plastic feed is available to the screw, check for faulty heater bands, and find out if the feed has 'bridged' (stuck together) in the hopper. Checking for bridging or material blockage in the machine feed throat requires caution and the immediate attention and expertise of trained personnel wearing the appropriate safety equipment. This is because of the potential for serious personal injury from the hot gases and degraded and overheated plastic that may spray violently back through the hopper.

Warming up a Full Machine

When material is in the barrel or die head, the machine is said to be full. A full, cold machine might result when there is a power failure or when the machine is deliberately shut down because of deterioration of the material by oxidation or depolymerisation. The machine must be heated in a safe way because decomposition produces gases under pressure and can cause serious accidents. To warm a cold machine, set all temperatures just below the melting temperatures of the material, for example, at 135 ºC for low-density polyethylene (LDPE). Allow the machine to reach and equilibrate at these temperatures, and then raise the temperature of the die (nozzle) to the process set point. To reduce the potential for dangerous pressure build-up in the barrel, wait for a period of time to allow the plastic in the die or nozzle to melt, and then raise the other barrel temperatures to the set point. Allow the machine to equilibrate to these temperatures before beginning to purge.

Initial Operation and Purging

When the machine is fully up to temperature, put a small amount of material in the hopper, make sure the hopper lid is in position and the hopper gate is open, and start the screw at 10-15 rpm. Do not allow the screw to turn in an empty machine, because this can damage the barrel and screw. Check to see that the set process conditions are correct by running for a minute or so on an extruder or by running a few purge cycles on an injection machine. A machine with a grooved barrel may require careful hand feeding of material by trained personnel, because it is easy to over-feed the machine.

After a short period of operation, check the melt temperature with a melt probe, and also the general appearance of the melt. Dispose of the hot, sticky plastic melt in a safe way once being satisfied that the material is feeding well, and the melt looks satisfactory. On an extruder, also check the drive motor current. It should be with the normal start-up range. If it is too high, there is probably unmelted material in the barrel. If it is too low, there may be feeding problems. On an injection moulding machine, material should fl ow freely from the nozzle. If it doesn't, the nozzle may be blocked by unmelted plastic. Do not attempt to clear a blockage by turning the screw or injecting under high pressure. If all is well, fill the hopper to the normal level for running. Check to see that the monitoring equipment is working, and in extrusion blow moulding, when material starts to extrude from the die, turn on the screw cooling if it is required.

Commencing Moulding – Manual Operation

When purging is complete and satisfactory melt is being produced, moulding may begin. The moulding process usually begins with manual operation, in which the operator initiates each part of the moulding cycle by pushing buttons according to the operation sequence. When the mould is closed, clamping pressure should be checked. To begin extrusion blow moulding, produce a parison and check its temperature and appearance. The parison must be long enough to reach the bottom of the mould for pinch-off. Start moulding, and adjust conditions and settings as needed to obtain a satisfactory part. Increase screw rpm gradually until it reaches the normal operating speed, while constantly checking the parts. A periodic check should be made to ensure that the hopper has enough material and that the melt is not leaking or weeping from around the nozzle/die/adaptor areas. Product quality should be closely watched to see that parts are free from froth or unmelted resin particles, and when the cycle is stable and the parts are good, production can begin. Note: If for some reason a different material was used for purging, it must be removed from the barrel according to procedures required by the material manufacturer, before moulding begins.

Commencing Moulding – Automatic Operation

Automatic operation is only started after satisfactory melt is made, after the purging procedure, and after the machine settings have been established based on experience or process records, or as determined from the manual operating conditions if this is a new product. Commence moulding on an automatic, or semi-automatic cycle (in which the operator opens and closes the safety gate to start the cycle) using pre-determined cycle times. These may be calculated, based on experience, or determined from the manual operating conditions. Gradually adjust conditions until product of the required quality is obtained at an optimum rate. After each adjustment, allow the machine to settle down for a reasonable time (approximately six cycles) before making further adjustments. With intermittent extrusion machines, adjust the cooling time until the moulding can be ejected without distortion. Screw start delays and screw speed (rpm) can be adjusted to fill this time.

Changing Conditions and Dimension Verification

Any changes must be well thought out in advance and should be made gradually. As an example, any increase in screw rpm may cause not only an increase in output but also an increase in temperature. Changes must be made one at a time. The machine must be allowed to settle down and the effect of the change noted, otherwise no one would know what is going on. Frequent or incorrect changes in the process can cause time to be lost and large amounts of scrap to be made.

Recording Production Conditions

The object of moulding is to make mouldings (parts) to the required specification (quality) and at the quoted cost. To do this, it is essential to keep accurate records. On many machines, data are recorded by computer. This data should be preserved. Critical parts, such as those for medical applications, have bar codes and the data are stored. When this is not possible, an appropriate record sheet should be completed initially and then periodically updated throughout the run. It is also good practice to keep sample mouldings. Logs of key events - the reasons, and observations are also useful.

Safety in Normal Machine Operation

Once the machine has settled in, controls and heaters should operate between an upper and a lower limit. This allows parts to be successfully made to specification. Most machines have process controls that warn when a condition is moving outside of a limit. The operator should advise the process technician so that the cause can be found quickly, and the problem corrected both to minimize the production of bad parts and to reduce the likelihood of hazardous overheating or excessive melt pressure.

Safety Considerations

Machines that are set to run automatically usually eject the parts onto a conveyor for finishing operations, so that the operator does not have to reach into the press. For some large industrial parts, an automated picker or robot picks the part from the press and delivers it to the finishing operations. Many times, particularly on small runs and when using a semi-automatic press cycle, the operator removes the parts by reaching into the press and removing the part from the mould. Redundant safety switches and devices must be in place and working to prevent the press from inadvertently closing on the operator. In all cases, the operator must wear gloves ('cooled' plastic parts are extremely hot to the touch when ejected), safety glasses, and usually earplugs. In plants with several different types of equipment running, the noise generated could damage hearing if protection is not worn. Entrances into plant areas that require sight, hearing, and sometimes helmet protection are usually marked with signs at the entrance indicating the type of safety protection required before entering the area.

Table 7.1 Safety standards for extrusion blow moulding machines	
Clause	**Safety Caution**
Operator's Gate	Operator's gate, window and mounting hardware to keep the operator away from hazards associated with moving parts and hot parison(s) including electric, hydraulic and pneumatic interlocks.
Power Operated Gates	A. Leading edges mounted with pressure sensitive switches to stop or open the gate. B. Closure of the gate shall not initiate cycle start.
Operator's Gate Electrical Interlock with Monitoring	To prevent all clamp, carriage, calibration or take-out motions when the gate is open.
Operator's Gate Hydraulic and Pneumatic Interlock with Monitoring	To prevent hydraulic or pneumatic powered motions when the gate is open including monitoring and alarm.
Emergency Stop Button	At least one emergency button to be provided near the point of operation.
Reset	Resetting a safety interlock shall not directly initiate a cycle.
Rear Guard	A fixed guard for the moulding area opposite the point of operation.
Top Guard	A fixed guard to prevent reaching over another gate or guard.
Additional Safety Requirement for Large Machines only	Presence sensing device; mechanical latch; double acknowledge system.
Emergency Stop	At least one emergency stop button in a walk-in mould area.
Blow Air Release	Monitoring of blow air to prevent mould opening under full blow pressure.
Part Discharge Opening	Guarding required near conveyor openings.
Windows to Moulding Area	All windows to conform to ANSI Z97.1 [2].
Guards	Fixed guards (or movable guards with interlocks) at all other hazardous points.
Guarded Feed Throat Opening	Guarding where access to the rotating feed screw is a hazard.
Extruder Barrel Covers	Cover or barrier to prevent inadvertent contact with high voltage or high temperature.
Window	All windows to conform ANSI Z97.1 [2].
Safety Signs	Safety sign kit to current standard.

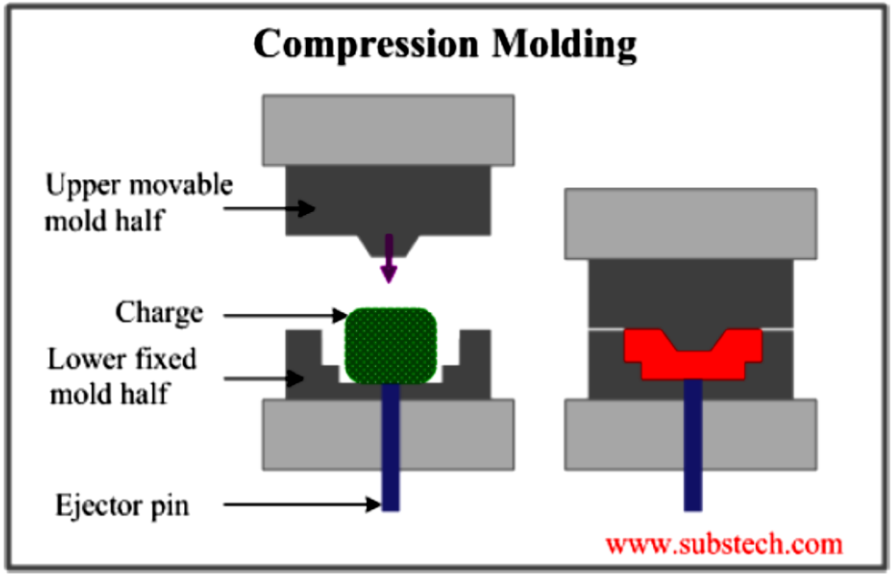
Table 7.2 Health and Safety Executive (HSE)	
Hazard	**Safeguard**
Dangerous moving parts in the mould area	Guards interlocking with the drive(s) (pneumatic, hydraulic or electrical) for the dangerous parts and sufficient fixed guards to complete the enclosure. The interlocking system should be dual channel and both channels should be monitored to prevent any further dangerous movement if a fault is detected.
Other dangerous moving parts	If not protected by the guard systems specified for the mould area, use: □ Fixed guards; or □ Distance guards positioned to take account of safety distances to prevent the operator reaching the danger zone; or □ Single-channel interlocked guards, monitored to prevent any further dangerous movement if a fault is detected. And for large machines a monitored, person sensing safety device should be installed, for example: □ A pressure-sensitive mat which extends between the mould; or □ An electro-sensitive device; or □ A mechanical latch which prevents involuntary guard closure and which can only be released from outside the mould area. Having triggered such a device, it should be necessary to do one of the following before initiating another cycle: □ Reset the safety devices □ Close the guards; and □ Actuate an enabling device to confirm the danger area is clear. Reset and enabling device actuation positions should provide a clear view of the danger areas. It should not be possible to actuate the enabling device from the danger area. Accessible emergency stops should be fitted on both sides of the mould. On large rotary machines they should be placed at intervals of 2 m or less inside the danger area.
Dangerous moving parts which can be reached through the delivery aperture	If not protected by the guarding systems specified for the mould area, use □ Fixed guards; or □ Distance guards positioned to take account of safety distances to prevent the operator reaching the danger zone; or □ Interlocked product delivery systems, monitored to prevent any further dangerous movement if a fault is detected. Such product delivery systems would include: – Single-channel interlocked guards, consisting of outward opening doors which are activated to let articles out but otherwise act as an interlocked guard; or – Two electro-sensitive sensing units arranged so they let articles out but prevent access; or – Other equally effective means, for example, pressure-sensitive mats built into the delivery system or scanning devices.
Power-operated guards	Either: □ Sensitive edges (fitted on both sides of the guard) which arrests or reverses guard closure; or □ A reduced-pressure closing system.

Shutting Down

A great deal of money can be saved by using the proper shutdown procedures. For example, if the material could be prevented from degrading or burning, a large amount of purging could be eliminated. Additional money would be saved if a complete machine shut down and cleanout were unnecessary, and start-up would certainly be easier.

Introduction to Compression Moulding:

Compression molding is widely used in the automotive industry to produce parts that are large, thin, lightweight, strong, and stiff. It is also used in the household goods and electrical industries.



For e.g., compression molded parts are formed by squeezing a glass fiber reinforced charge inside a mold cavity. The matrix can be either a thermoset or thermoplastic. The most common matrix used to manufacture compression molded articles is unsaturated polyester sheet reinforced with glass fibers, known as sheet molding compound (SMC). The 25 mm long reinforcing fibers are randomly oriented in the plane of the sheet and make up for 20−30% of the molding compound's volume fraction. A schematic diagram of an SMC production line is depicted in Fig. 7.26. When producing SMC, the chopped glass fibers are sandwiched between two carrier films previously coated with unsaturated polyester-filler matrix. A fiber reinforced thermoplastic charge is often called a glass mat reinforced thermoplastic (GMT) charge. The most common GMT matrix is polypropylene. During processing of thermoset charges, the SMC blank is cut from a preformed roll and is placed between heated cavity surfaces. Generally, the mold is charged with 1 to 4 layers of SMC, each layer about 3 mm thick, which initially cover about half the mold cavity's surface. During molding, the initially randomly oriented glass fibers orient, leading to anisotropic properties in the finished product. When processing GMT charges, the preforms are cut and heated between radiative heaters. Once heated, they are placed inside a cooled mold that rapidly closes and squeezes the charges before they cool and solidify.

Important Variables during Processing

In compression molding, thermoset materials determine the pressure required to produce molding with minimum cycle time. Important variables such as

- Product design in terms of:
    - projected area and depth
    - wall thickness
    - obstructions such as sharp corners, pins, etc.
- Press speed, slow versus fast
- Self-contained versus hydraulic system
- Ability to maintain holding pressure during molding
- Material plasticity being processed:
    - pre-heating conditions
    - compound density (pre-form or powder)
    - material position placed in die.
    - compound flow properties under pressure
    - filler material and concentration.
- Overall mold temperature and its uniformity
- Mold surface condition
- Mold pressure.

Troubleshooting

Today process parameters are often found by trial and error rather than by process simulation because simulation software is often considered suitable for industrial applications. Compression molding is facing many challenges to meet a rapidly changing and diversifying market environment. There are many problems encountered in the process with associated inherent complexities in terms of:

- Kinetics
- Mechanisms
- Physical changes

- Transport effects such as:
  - o viscosity increase
  - o particle formation
  - o inter-facial mass and heat transfer limitations.

The end-use applications are often represented by non-molecular parameters such as:

- Tensile strength
- Impact strength
- Color
- Crack resistance
- Thermal stability
- Density, etc.

These must be somehow related to fundamental polymer properties such as:

- Composition
- Branching
- Cross-linking
- Stereo-regularity, etc.

Unfortunately, process variables affect properties and the relationship between the process variables and end-use properties is generally very difficult and not well established. In situ real-time monitoring of compression molding is of crucial importance to polymer scientists and engineers engaged in efforts to optimize processes and products. Moreover, many process variables that affect product quality namely non-ideal mixing and conveying, and strong process non-linearity related to limited cycles and multiple steady states. Two big expenses for any processing are:

- Failure to quickly and accurately troubleshoot process upsets and equipment problems
- Failure to realize the operating potential of its process through optimization
- Minor upsets and equipment problems which are not identified and resolved quickly can progress into much larger problems potentially resulting in:
  - o lost production
  - o off-spec product
  - o equipment loss
  - o catastrophic accidents.

Additionally, operating a process at suboptimal performance results in elevated operating costs due to:

- Increased energy costs
- Equipment reliability costs
- Lower yields
- Longer startups, etc.

Therefore, the ability to troubleshoot and optimize process operations are two of the most valuable skills operation personnel can possess. Troubleshooting requires a comprehensive analysis of:

- The process
- Mold design
- Material

Compression molding tends to focus on process modifications to solve problems. There may be longer cycle times, secondary rework operations or formulation modifications that negatively impact profits. Thorough and systematic analysis can pinpoint the exact problem cause and identify the most cost and time-effective solution.

Problems and Solution(s)

Compression molding is widely used in the automotive industry for producing exterior body panels. For the last two decades, and in spite of many cosmetic problems, compression molded parts usage has increased for exterior body panels such as hoods, deck lids, and door panels. The cosmetic problems most commonly observed in compression molded parts are sink marks over ribs and bosses, long term waviness, and surface porosity. Painting or coating the molded part can be very effective in providing a cosmetic surface free from substrate porosity. A low-profile agent such as thermoplastic material mixed with the resin just prior to compounding has been found to reduce the polymerization shrinkage as it cures in the mold and in turn reduces sink marks and long-term waves observed on the part surface. Using coatings and low-profile additives has reduced sink marks. However, sink marks can still exist in the molded parts. To solve the sink mark problem, one must style and design surface contours so that sink marks are concealed. Jutte et al. studied the role of polymerization and thermal shrinkage and concluded that the polymerization shrinkage can be minimized by using low profile agents. Thermosets are inherently brittle, organic additives can be used to improve the fracture toughness of these materials. For thermosets, that are lightly cross-linked, reactive oligomers that phase separates during cure help and for highly cross-linked thermosets, thermoplastic toughening agents can be used. During pressing the temperature and the pressure are substantially increased. This means that even large voids can be dissolved in a very short time. If the pressure is large enough within the resin most enclosed gas should dissolve and SMC products ought to be completely free from voids. It is well known that these items can have a relatively high void content. There are several reasons for this. Still some issues are unresolved such as fiber reorientation during processing, which strongly affects the final SMC strength and residual void formation which can cause large surface defects after painting and lower the electrical insulation capacity of the part manufactured.

The voids located in the SMC during pressing may have entered the SMC via:
• the constituents when they are mixed to form the SMC
• being enclosed during the lay-up procedure
• or formed as the charge flows in the mold during pressing.

It may also happen that during the curing process the pressure becomes too low and SMC constituents such as styrene start to boil. Regardless of how the voids form, their final size and location are strongly affected by the fluid pressure in the SMC during compression. Specifically, it has been observed that the formation, movement, and number of voids are strongly related to the temporal and spatial distribution of the pressure and the pressure gradients, where high pressures, and pressure gradients, generally gives a low residual void content since it enables the voids to move forward through fiber networks or dissolve into the resin. The SMC consists of fibers, caulk, and some additives that may considerably slow down the dissolution of gas. Low-pressure zones are formed during pressing. This may be due to uneven filling or, complex shaped molds or uneven solidification. A substantial amount of gas is dissolved during the compression which saturates the resin much faster than predicted in the model. This could be a reasonable explanation if air is trapped between the sheets during charge lay-up. Molding cycles are longer with the need to remove flash from the parting line and holes. Difficulties in molding side holes or sections, and problems with molding in flash free metal inserts have all contributed to reduced use of compression molding.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video links:

Plastic Injection Molding – University of Illinois: https://www.youtube.com/watch?v=RMjtmsr3CqA
Molding Machine Parts and Operation - Technology of Injection Molding: https://www.youtube.com/watch?v=DbaWBXe9-vQ
Instructional video: 80 Ton Arburg Injection Molder: https://www.youtube.com/watch?v=VxayepUk3r0
Extrusion machine process (Hindi): https://www.youtube.com/watch?v=tbsApGggYGA
Plastic Extrusion - Safety, Pre-Start and Start-Up Procedures: https://www.youtube.com/watch?v=2rzhevw2Ong
Plastic Extrusion - Operation, Shutdown and Maintenance Procedures: https://www.youtube.com/watch?v=Rf5DQR5qXxU
Extrusion Blow Molding - Lesson 3 - Extrusion Blow Molding Operating Controls: https://www.youtube.com/watch?v=YWzaZYHXS9s
Processing of Plastics- Compression and Transfer Moulding: https://www.youtube.com/watch?v=A1XKGUH7wRQ
What is Compression moulding process in hindi: https://www.youtube.com/watch?v=NlJqDPlnDXY
Compression Moulding Process: https://www.youtube.com/watch?v=sus8arkJOeA

PLASTIC PROCESSOR

Module-8

Learner Guide

National Vocational Certificate Level 4

Version 1 - September, 2018

Module 8: 072200920 Perform Tool Change-over

Objective of the module: The aim of this module to provide skills and knowledge to performance of tool change over to machine in accordance with the manufacturer's manual

Duration: 150 hours **Theory:** 30 hours **Practical:** 120 hours

Learning Unit	Learning Outcomes	Learning Elements	Duration	Materials Required	Learning Place
LU1: Obtain work order	**The trainee will be able to:** Collect work order from relevant department. Interpret work order as per organizational procedure. Read existing job order sheet/card. Communicate pre completion of existing job order to relevant department.	i) Basic literacy skills • Be able to read instructions about product, quantity and raw material • Be able to identify rolling required to produce different components as per work order ii) Reporting procedure • Understanding the work order contents • Knowledge of units (Kg, inches, etc.) iii) Work order process • Understand the top-down stream of task assignment • Knowledge of what the work order represents • Who generates the work order? • Where can it be obtained from?	**Total** 10 hours **Theory:** 02 hours **Practical:** 08 hours	Moulding machine/extruder Mould/die Utility documentation	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

		iv) Tool handling and storing procedure • Understanding where to obtain desired tool • How to handle mould and dies? v) Set machine parameters as per data sheet provided vi) Be able to input machine parameters as mentioned in work order or datasheet			
LU2: Prepare tool for production	**The trainee will be able to:** Line up tools according to work order. Clean tool according to instruction manual and procedure. Check quality report before installation.	i) Understanding of Tool design and utilities • Identification of correct tools for the job • Softer materials to be used for brushing and cleaning of polished metal surfaces ii) Tool handling protocols • Understanding the concept and appreciating importance of PPEs iii) Tool cleaning protocols	**Total** 50 hours **Theory:** 10 hours **Practical:** 40 hours	Moulding machine/extruder Mould/die Utility documentation Basic tools Die/mould handling equipment Safety gear	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU3: Carry out tool installation	**The trainee will be able to:** Arrange required hand/ power tools and accessories for installation.	i) Handling of hand/power tools ii) Understanding of hydraulics/pneumatics and water lines iii) Tool design	**Total** 50 hours **Theory:** 10 hours **Practical:**	Moulding machine/extruder Mould/die Utility documentation Basic tools	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities

	Check hydraulic/ pneumatics, and water lines. Perform Installation of tool (Mould/die) Ensure level/alignment of tool with machine.	iv) Tool alignment and fixture v) Training of crane operations	40 hours	Die/mould handling equipment Safety gear	**OR** Visit to a training institute with relevant facilities
LU4: Carry out tool storage	**The trainee will be able to:** Arrange required hand/ power tools and accessories for offloading Apply anti rust coating on tool (Mould/Die). Drain cooling media before offloading of Tool. Perform offloading as per instruction manual and procedure. Prepare and submit remarks sheet as per standard. Clean and shift tool (Mould/Die) for storage in designated area.	i) Utilization of tool handling accessories, such as cranes, etc. ii) Pre-storage Tool protection treatments iii) Tools transportation SOPs iv) Be able to hand over unused tools to store • Familiarize with handing-over protocols and paperwork.	**Total** 40 hours **Theory:** 08 hours **Practical:** 32hours	Mould/die Utility documentation Basic tools Die/mould handling equipment Safety gear	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

Examples and Illustrations:

For more details please refer to these books:

1) Training in Injection Moulding, 2nd Edition, by HANSER Publishers, Munich.
2) Understanding Polymer Processing, by Hanser Publishers, Munich
3) Extrusion: The Definitive Processing Guide and Handbook by © 2005 William Andrew Publishing
4) The Dynisco Extrusion Processors Handbook 2nd Edition by John Goff and Tony Whelan, The DYNISCO Companies
5) Practical Guide to Blow Moulding Technology by Norman C. Lee, © 2006 Rapra Technology Ltd.
6) Handbook of Troubleshooting Plastics Processes by © 2012 Scrivener Publishing LLC, Chapter 18: Compression Moulding
7) Presentation on Compression Moulding, 2008 AMD 2927, IIT Delhi, by Chandra Shekhar Thakur

The primary tasks of an injection molding tool consist of accommodating and distributing the melt, the forming/shaping and cooling of the molded article and its removal from the mold. (With thermosets/elastomers: also, the introduction of activation/curing energy). The secondary tasks of absorbing the forces, transmitting motion, and guiding the molded parts are derived from these primary tasks. To clarify the tasks and functions of an injection mold, it is best to follow the path of the material within the injection molding machine all the way to the development of the finished article. The material has been conveyed into the injection chamber during the course of the plasticating phase. Along the way it has been melted and homogenized. The prepared, flowable material is transported from the injection chamber of the plasticating and injection unit into the mold. In other words, it is 'injection molded.' The impression space into which the molding compound is injected – known as cavity - is located within the mold. The material solidifies by cooling within the cavity, thus forming the molding. With thermosets/elastomers, the article is produced by chemical crosslinking reaction. Each cycle of the injection molding process often produces only one molding. In this case, we speak of a 'single-impression mold'. The number of parts produced in each cycle can exceed 100 (for example, small silicone moldings). This involves the use of 'multi-impression molds' (see Figure 4-1).

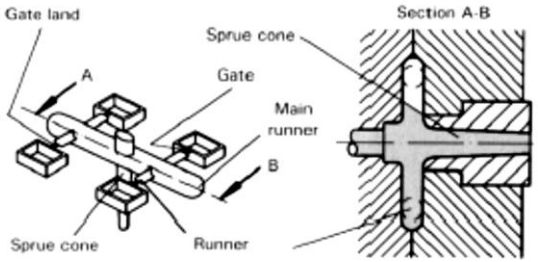


Figure 4-1 Gating and runner system for a four-impression mold

Basic Principles

The molding compound flowing from the nozzle enters the mold and is distributed into the cavities. This is the task of the sprue- and runner system (see Figure 4-1). It consists of several sections, that may differ in design, subject to requirement. As the melt leaves the nozzle, it passes through the sprue bush and into the runner, which connects to the gates of the cavities. The demands placed upon gating and runner system can be described in a single sentence:

The gating and runner system must be so designed, that homogenous melt fills all cavities simultaneously and uniformly at equal pressure. The runner system is designed to suit the position of the cavities in the mold. Position and design of gates to cavities is primarily a function of the molded article's design and its specifications.

The sprue- or bar gate (Figure 4-2) represents the simplest kind of gating. It is used for thick-walled moldings and offers little resistance to the melt because of its large cross section. Its conical shape allows the melt to flow easily.

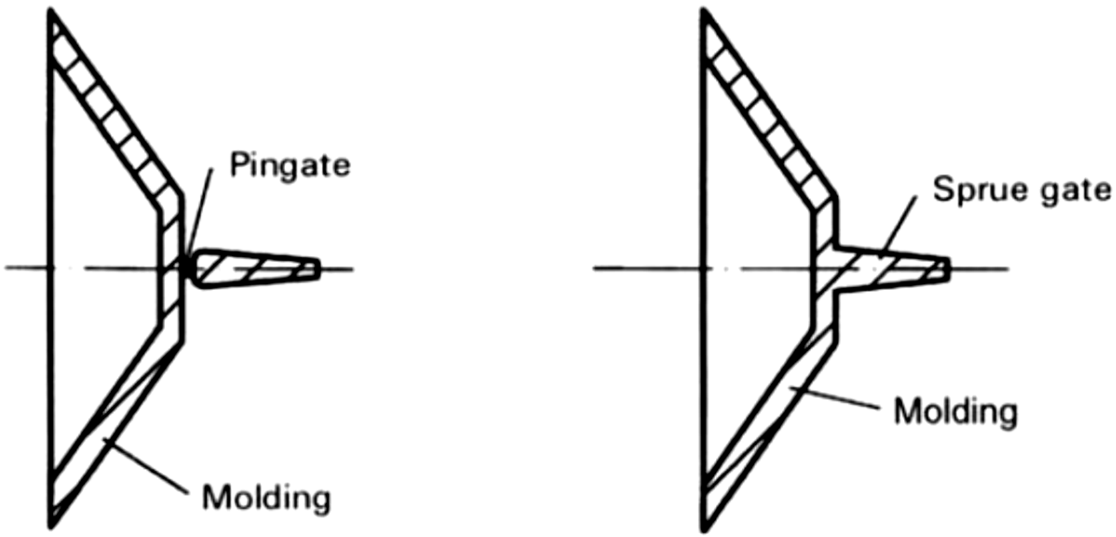


Figure 4-2 Sprue-gate and pin-gate

When the molding is ejected, the sprue is pulled off at the (warmer) nozzle end. Therefore, the stem remains on the molding and must be removed by an additional operation. The sprue-gate is employed on high quality technical articles and on thick-walled moldings. In contrast, the pin gate (Figure 4-2) is pulled off at its connecting point on the molded article, when this is removed. The pin gate thus leaves only a small mark on the molded part, requiring little or no finishing. Fully automatic de-gating is possible.

The diaphragm gate (Figure 4-3) is employed with axially symmetrical round articles. Initially, the melt is evenly distributed across the diaphragm gate and then flows uniformly into the cavity. This method prevents weldlines, which would occur, if several gates were used. This type of gate will subsequently have to be severed however.

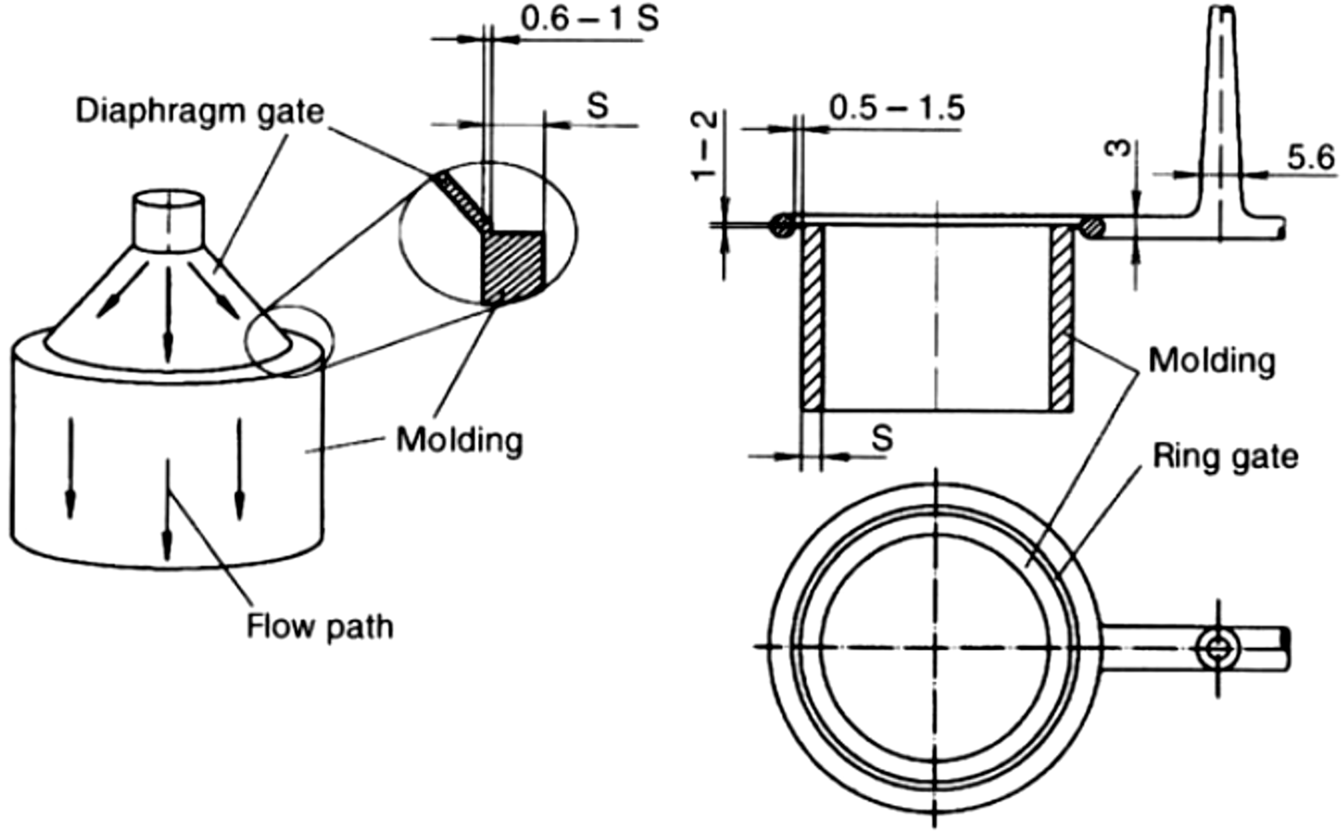


Figure 4-3 Diaphragm- and ring-gate

The ring gate is employed for round or sleeve-like articles, whose core -due to its length -needs supporting bilaterally. This enables even long-cored articles to be molded at an all-round consistent wall thickness. The film gate (Figure 4-4) functions to the same principle as the diaphragm gate. It is used with flat moldings and assists cavity filling. (Leaves neither weld-lines nor other markings on the article's surface).

The tunnel gate (Figure 4-4) is mainly employed with multi-impression molds for small articles, as well as flexible molding compounds. The tunnel-like gate creates a sharp edge between mold guidance and tunnel, which separates the sprue-system from the article on demolding, thus ensuring automatic severance.

All the different sprue versions shown thus far share the disadvantage, that material is wasted in the gate- and runner-system. Only a portion of this material can be returned to the process by "internal recycling systems." For reasons of cost and environmental protection, an attempt is made to avoid such material wastes, by controlling the temperature of the gate- and runner-system in order to maintain the flowability of the melt in this area.

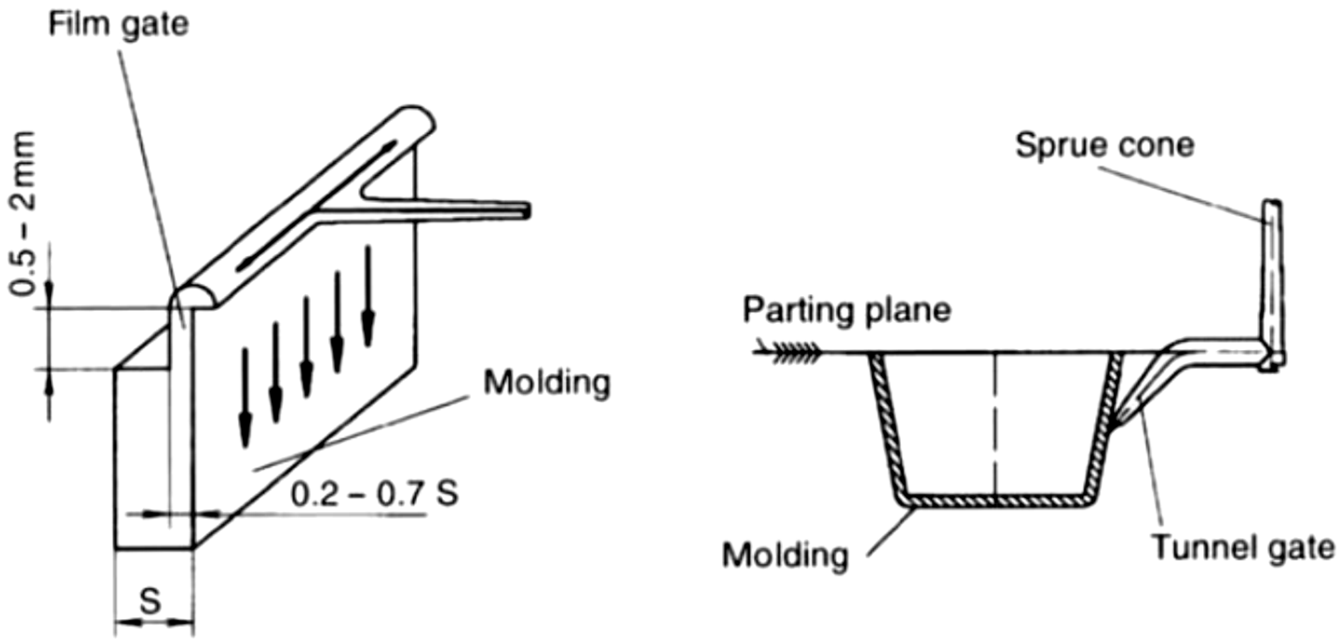


Figure 4-4 Film- and tunnel-gate

Hot runner systems are therefore used in the processing of thermoplastics. However, the processing of elastomers involves the use of cold runner systems, which prevent the elastomer compound from cross-linking prematurely in that system (see Figure 4-5).

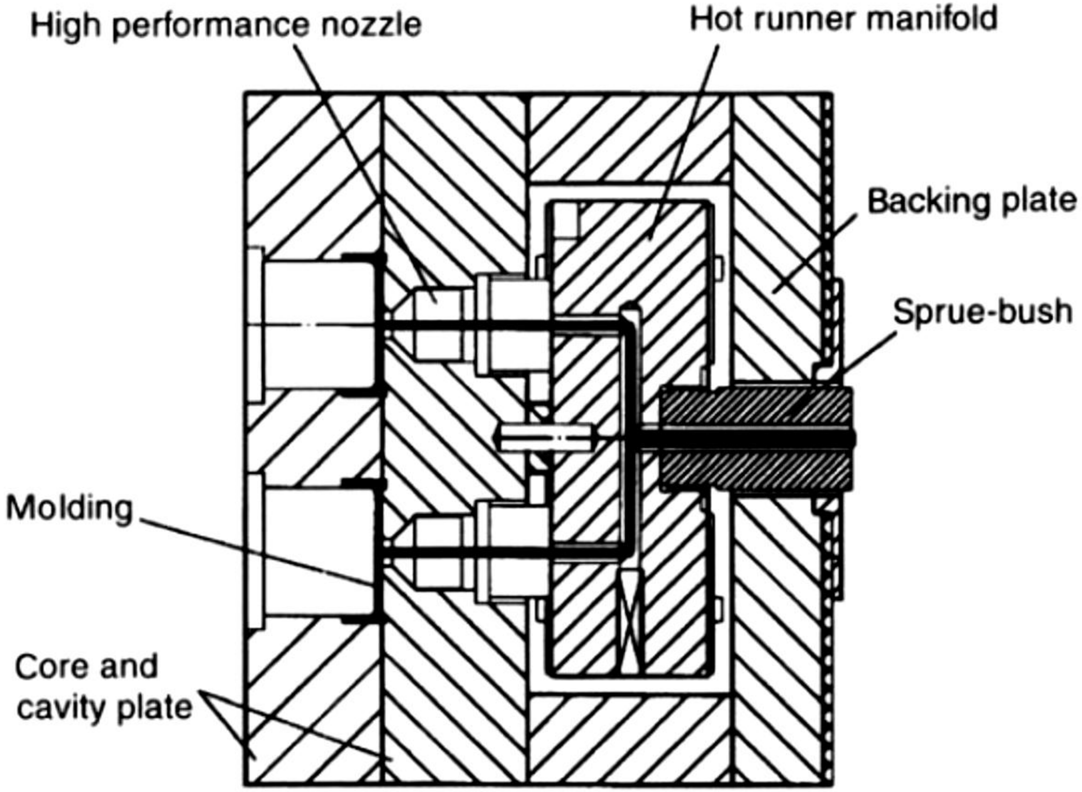


Figure 4-5 Hotrunner system

The more complicated and demanding articles for injection molding become, the fewer of them it will be possible to process simultaneously (i.e., in a single shot). The reason is, that the process will have to be monitored very precisely, in order to achieve the required properties. The more cavities a mold has, the more difficult it becomes to ensure, that each part is made under identical process conditions. Therefore, even hot runner systems are mostly employed in molds of few cavities only.

The CD is an example of such a complex molding described. It is subject to very demanding optical requirements. The CD is manufactured in a single cavity mold by using a type of cone gate, which is punched out after the part has been removed from the mold. First signs of moving towards hot runner systems for this application are also apparent.

Cavity

The flowing material passes through the gate and runner system into the mold cavity or cavities. Here the molding is formed by solidification of the molding compound (thermoplastics), or by crosslinking reaction (elastomers, thermosets). A mold cavity (the ‘casting mold’ proper), is an exact negative image of the article being produced (see Figure 4-6). As with any casting process, however, the solidification of the molding compound brings about a decrease in the volume of the part being made. In other words, the molding shrinks. Any type of casting mold- including the cavities in the injection molding process - must therefore be made slightly larger than the finished article. This extra dimension must equal the volume, that will be lost in shrinkage. In this manner, finished parts are produced to the correct dimensions. Examples include gears which are suitable for mounting in the drive mechanisms of kitchen appliances. The shrinkage of amorphous thermoplastics amounts to 0.5-0.8%. In part-crystalline thermoplastics it is 1-2%.

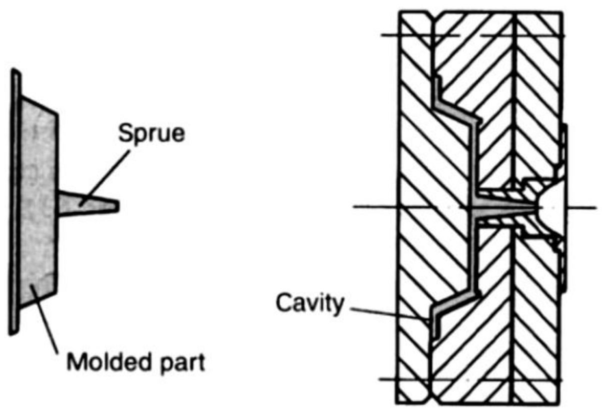


Figure 4-6 Example of a mold cavity

Beside shrinkage - which is determined by the material - there is also another type of dimensional deviation between the cavity and the finished molding, namely ‘warpage’ (see Figure 4-7). One example of article warpage is the apparent slight bending of long, flat surfaces.

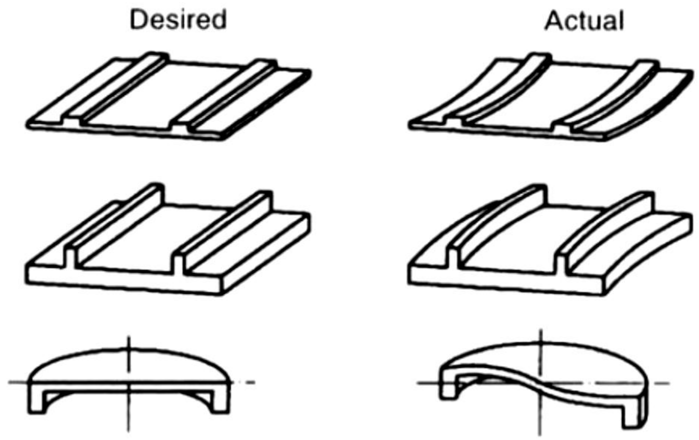


Figure 4-7 Warpage

Warpage develops as a result of different cooling rates in areas of the molding, which vary in thickness. Warpage is also caused by orientations, that develop during the injection process. Orientations consist of the preferred directional alignments of the injected material’s macromolecules. Because long, flat surfaces on the molding are often unavoidable, ribs are used to reinforce the article’s critical sections whenever possible. These ribs prevent deflection. Examples for this are housings for television sets, or doors on copying machines. When ribs cannot be used, other countermeasures must be employed. It is possible, to modify the mold cavity in such a way, that the finished article turns out straight through subsequent ‘warpage’. This means, that warpage has been allowed for during the mold’s design stage already. Another possibility is the employment of the gas injection technology. Gas is introduced systematically to generate a holding pressure in certain local areas, to counteract shrinkage and thus warpage.

The gate usually produces a mark on the finished molding. Naturally, this mark should not occur in an especially visible part of the article. At the same time, however, there is a limit to the allowable complexity of the runner system’s design. This is also a function of the maximum permissible flow-path length for the plastics material chosen, or the additional loss of material caused by a larger runner system. For these reasons, the position of the cavity within the mold is also subject to restrictions in some cases. Other limitations with the position of mold cavities arise from the ease, with which the molded article can be removed from the mold, without suffering damage.

Heating/Cooling Systems

The goal is to produce a solid, stable molding from the melt within the cavity. As explained earlier, thermoplastics have to undergo a solidification process, whereas thermosets/elastomers are subjected to a chemical crosslinking reaction. We will examine this solidification process more closely, especially as it applies to thermoplastics. When a thermoplastic is processed, it is heated while in the plasticating unit. This heat is sufficient for the material to melt and for this melt to be injected into the mold cavity. That heat must then be removed from the melt in the mold, so that it can solidify into the final article. A mold employed for thermoplastics must therefore be able to carry heat away from the molding. The situation is different in the processing of reactive molding compounds (i.e., elastomers and thermosets). In fact, a certain amount of heat is introduced to these compounds in the plasticating unit to render them fluid. However, the article in the mold is not solidified by the hardening of the melt but by a chemical cross-linking reaction within the material. Heat is needed to set this reaction in motion. To mold an article from a reactive compound, the mold must therefore be capable of introducing heat into the molding.

These two demands on the injection molding tool are thus fundamentally different. Therefore, there can also be great structural differences between molds used for the processing of thermoplastics and those employed for the processing of reactive molding compounds. For cooling purposes, molds used for the processing of thermoplastics are provided with channels in the vicinity of the cavity. Water flows through these channels. Figure 4-8 shows the structure of a heating system employing a liquid medium. To create a network of channels, longitudinal and transverse channels are drilled in the mold. These channels are then closed at certain positions, in order to create a circulation system for the heating/cooling medium. The temperature of this medium is usually between 30 and 100°C (86-212°F). The exact temperature depends on the molding compound.

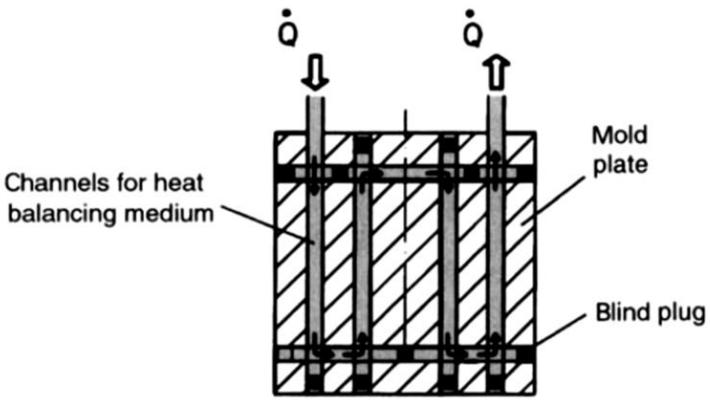


Figure 4-8 Heating system employing a liquid medium

Electric cartridge heaters are often used to heat elastomer molds and thermoset molds. Figure 4-9 shows a schematic diagram of an electric heating system. In this case, cartridge heaters are inserted into bores in the mold to achieve temperatures of 150-200°C (300400°F) required for cross-linking.

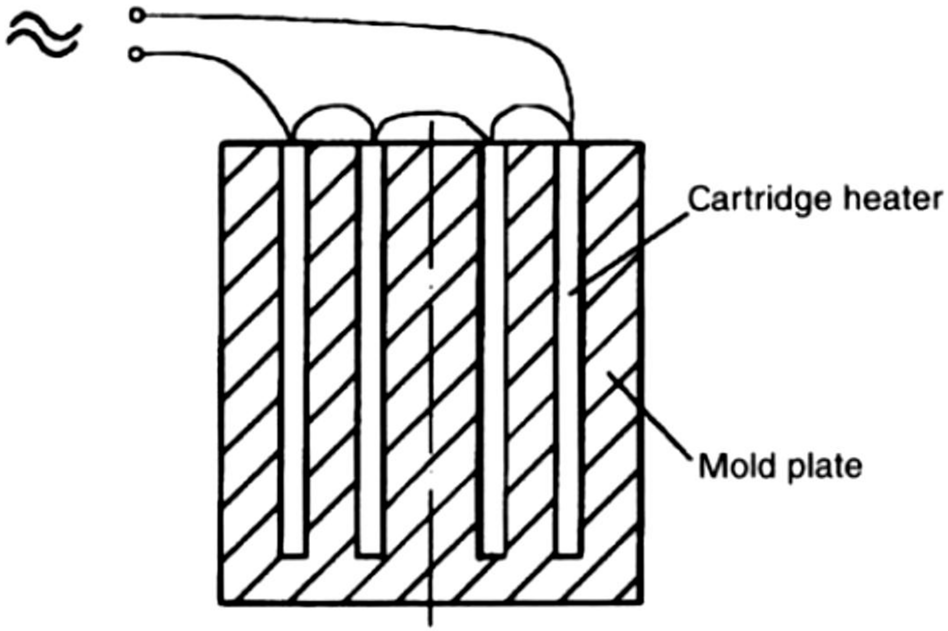


Figure 4-9 Schematic diagram of an electric heating system

It is also possible to employ a heat-balancing system, using a liquid heating medium. Due to the high temperatures involved, heat transfer oil is used primarily.

The general term heat-balancing is used, because heat is being conducted in each case: either away from the cavity for thermoplastics (cooling), or toward the cavity for thermosets and elastomers (heating).

Ejection System

Once the molding has solidified within the cavity at the end of the cycle, it is important to ensure, that the finished article can be removed from the mold. For that purpose, the mold consists of two halves, so that it can be opened at the parting plane. Figure 4-10 shows an open mold. In this diagram, the molding is being removed by the ejector.

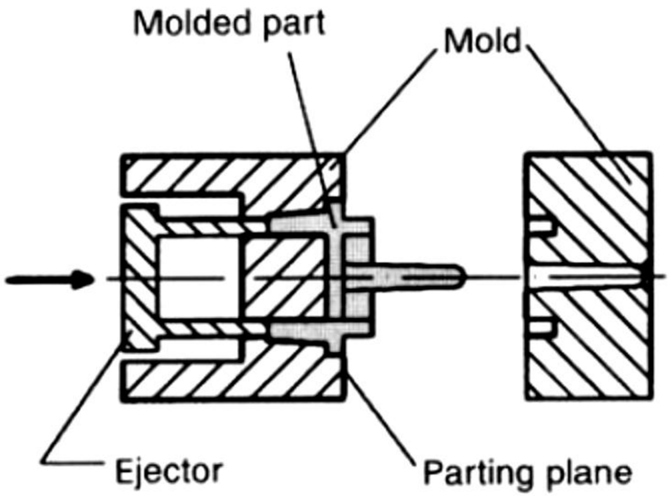


Figure 4-10 Mold and parting plane

As soon as the mold has been opened, the article can be removed at the parting plane. In the simplest cases, this can be performed manually. However, the injection molding process is designed specifically for mass-producing articles at a fast rate and should ideally operate in fully automatic mode. It is therefore obvious, that manual removal takes too much time. Furthermore, the cycle time fluctuates as a result of the operator's intervention in the machine cycle. This can cause variations in the molding's quality. With thermoplastics, manual removal is used only in exceptional cases, where articles are delicate or of complex shape.

The situation is somewhat different for elastomers. On the one hand, the elasticity required in the application of molded rubber parts makes automatic removal within the injection molding cycle more difficult. On the other hand, there are certain complicated article geometries, which it would be impossible to produce profitably by the injection molding method, if it were not for the flexibility of these parts. Examples include bellows and elbows for hoses. It is therefore often impossible to avoid the manual removal of rubber moldings, even in large-scale production. Removal is generally performed by automatic ejectors, which are operated by the machine when the mold opens in the parting plane at the end of the injection molding cycle. These ejectors ensure, that the article is separated from the surrounding cavity in spite of undercuts, adhesive forces, and internal stresses which tend to retain the part within the cavity. A wide variety of ejector designs may be used. The choice depends on the shape of the article, its position within the mold, and the force retaining it. Figure 4-11 shows a pin system as an example of an ejector in an injection molding tool.

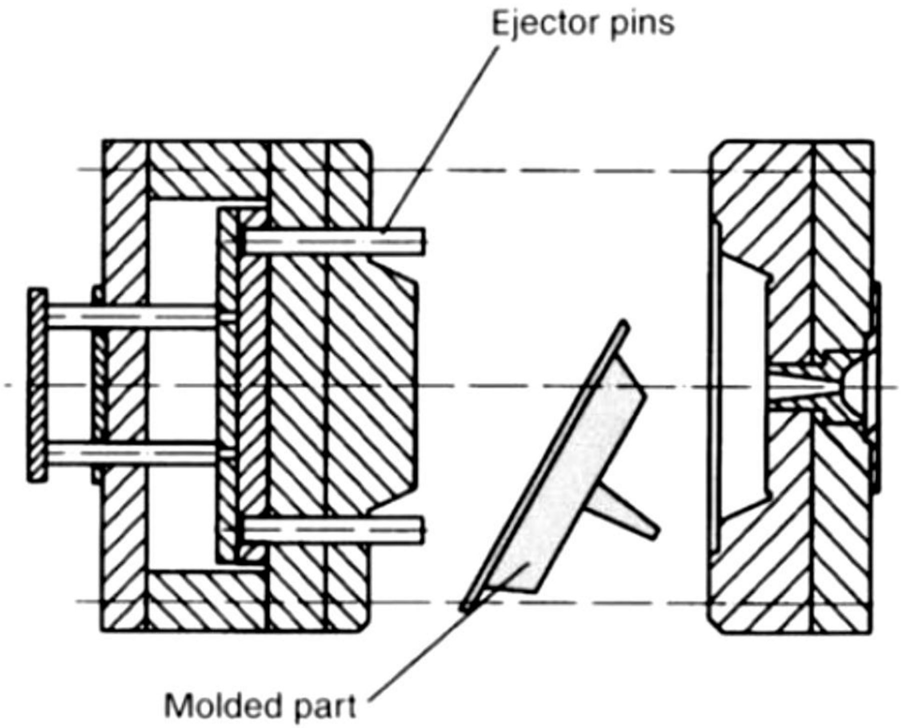


Figure 4-11 Demolding by ejector pins

Ejector pins often leave compression marks on the molded article. They should not be used on the visible part of the article, if this can be avoided. Another example of an ejector is the sleeve-ejector (Figure 4-12), which is able to transmit greater ejection force. Sleeve-ejectors are primarily employed with moldings, which are axially symmetrical.

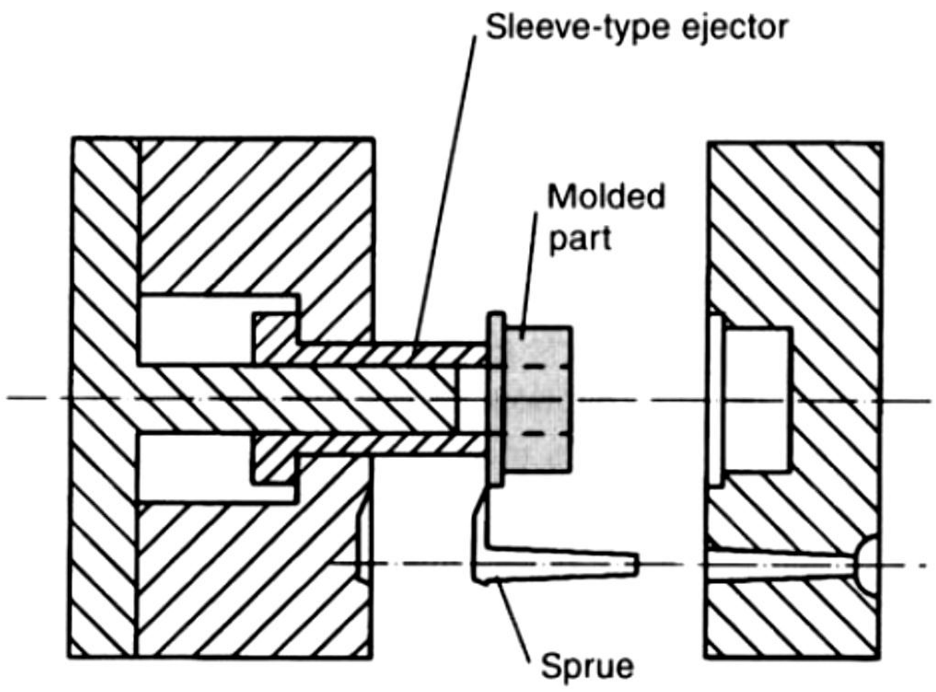


Figure 4-12 Demolding by sleeve-ejector or push-off bush

If the molding possesses undercuts, it is often insufficient to merely provide the ejectors with a design suitable for trouble-free removal. In such cases, the mold must be designed with an additional parting plane, which also opens during demolding, releasing the undercut. Figure 4-13 shows an example, in this case a splits mold.

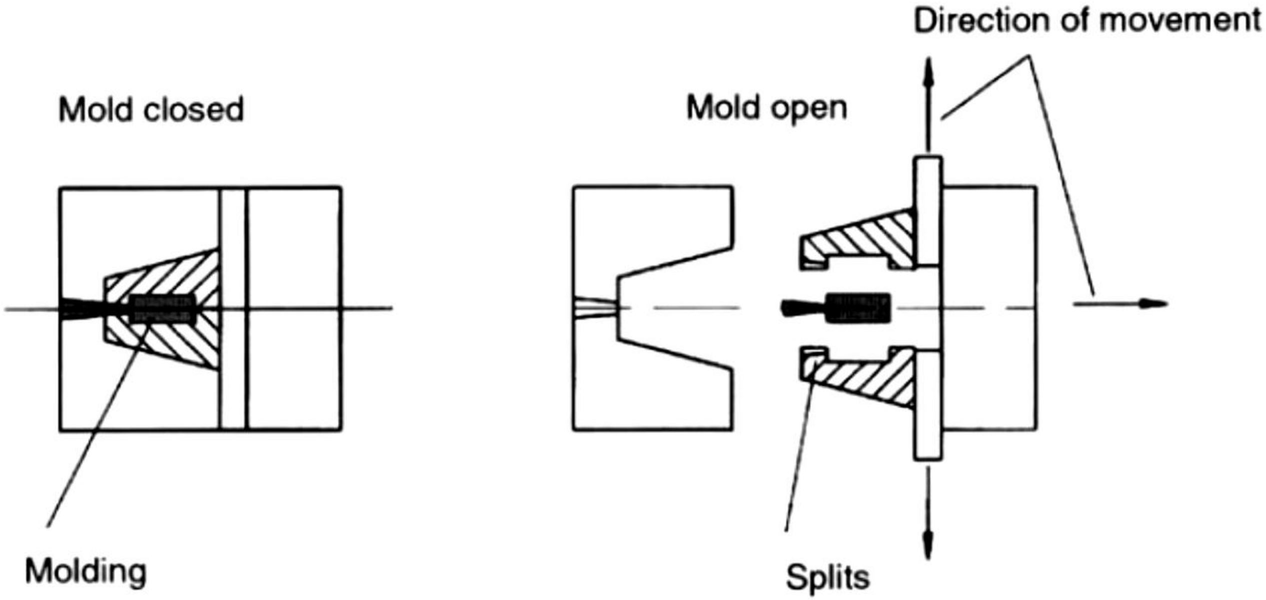


Figure 4-13 Splits mold

Where article specifications are not very demanding, the molding may drop onto a conveyor belt or into a receptacle, after ejection from the mold.

Exact moldings with high-quality surfaces (e.g. car bumpers), must be removed with a handling device, in order to prevent damaging the article. Such handling devices include robots, for example. There is another advantage to using handling devices: when an additional finishing operation is required for the article, after the injection molding process. In that case, the gripper can immediately place the molding in the correct position for the finishing procedure. This saves time and effort, which would otherwise be wasted by additional sorting.

The CD is an example of a very demanding part which must be removed by a handling device. If the CD were removed by simply allowing it to drop onto a conveyor belt by the force of gravity, it would probably be damaged so severely that it could no longer fulfill its intended function. Another benefit is, that the robot can transport the CD directly into the “sputtering” (metal coating) station.

Extrusion Dies

The extrusion die shapes the polymer melt into its final profile. The extrusion die is located at the end of the extruder and it used to extrude:

- flat films and sheets
- pipes and tubular films for bags
- filaments and strands
- hollow profiles for window frames
- open profiles

As shown in Fig. 4.18, depending on the functional needs of the product, several rules of thumb can be followed when designing an extruded plastic profile. These are:

- Avoid thick sections. They add to the material cost and increase sink marks caused by shrinkage.
- Minimize the number of hollow sections. hollow sections add to die cost and make the die more difficult to clean.
- Generate profiles with constant wall thickness. Constant wall thickness in a profile makes it easier to control the thickness of the final profile and results in a more even crystallinity distribution in semi-crystalline profiles.

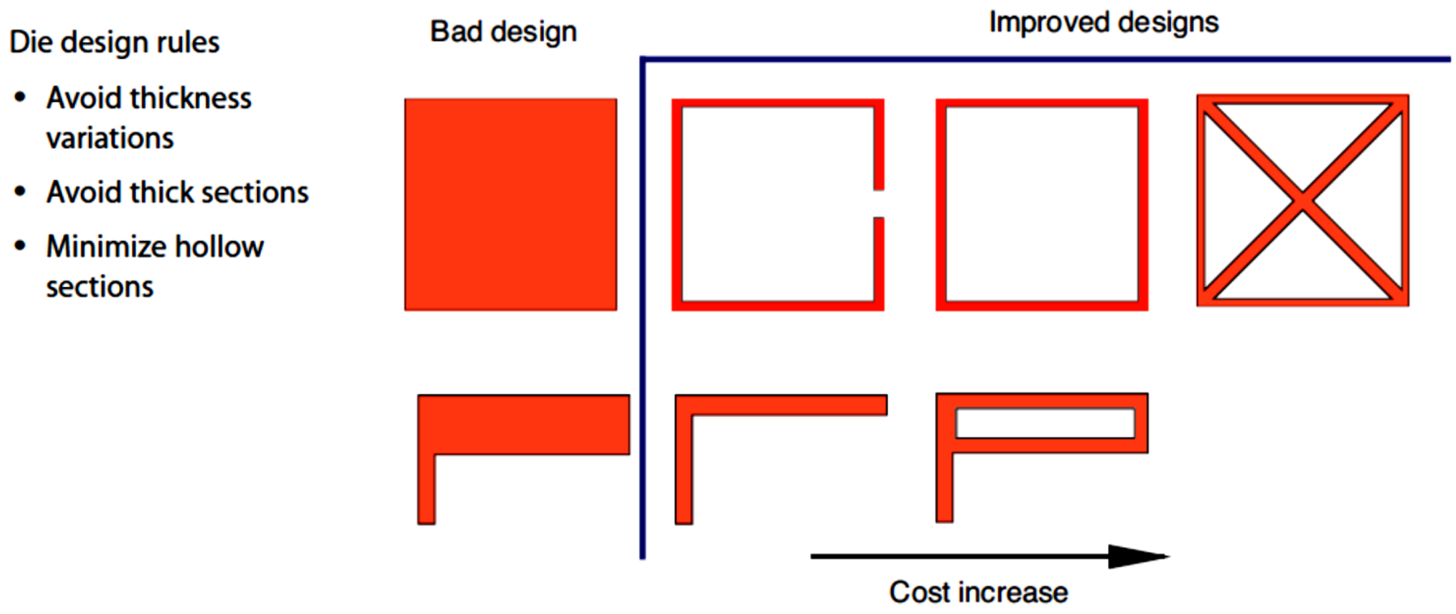


Figure 4.18 Extrusion profile designs

Sheeting Dies

One of the most widely used extrusion dies is the coat-hanger sheeting die. A sheeting die, such as depicted in Fig. 4.19, is formed by the following elements:

- Manifold: evenly distributes the melt to the approach or land region
- Approach or land: carries the melt from the manifold to the die lips
- Die lips: perform the final shaping of the melt
- Flex lips: for fine tuning when generating a uniform profile

To generate a uniform extrudate geometry at the die lips, the geometry of the manifold must be specified appropriately. Figure 4.20 presents the schematic of a coat-hanger die with a pressure distribution that corresponds to a die that renders a uniform extrudate.

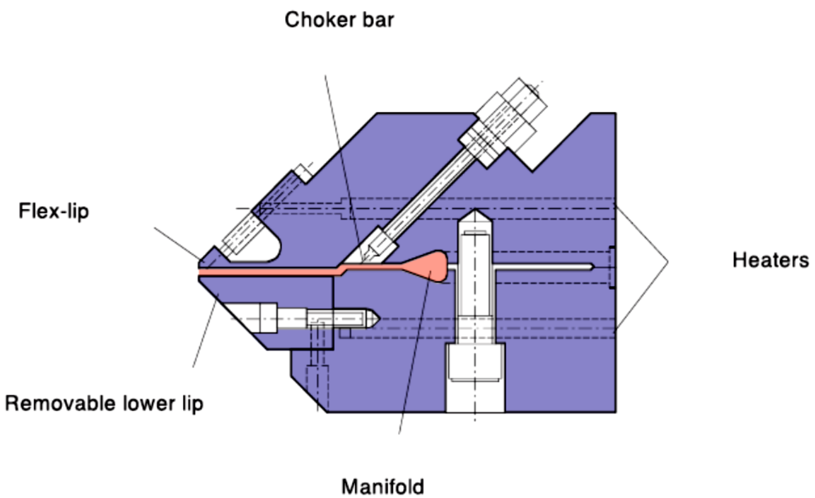


Figure 4.19 Cross section of a coat-hanger die

The goal in sheeting die design is to have a uniform product

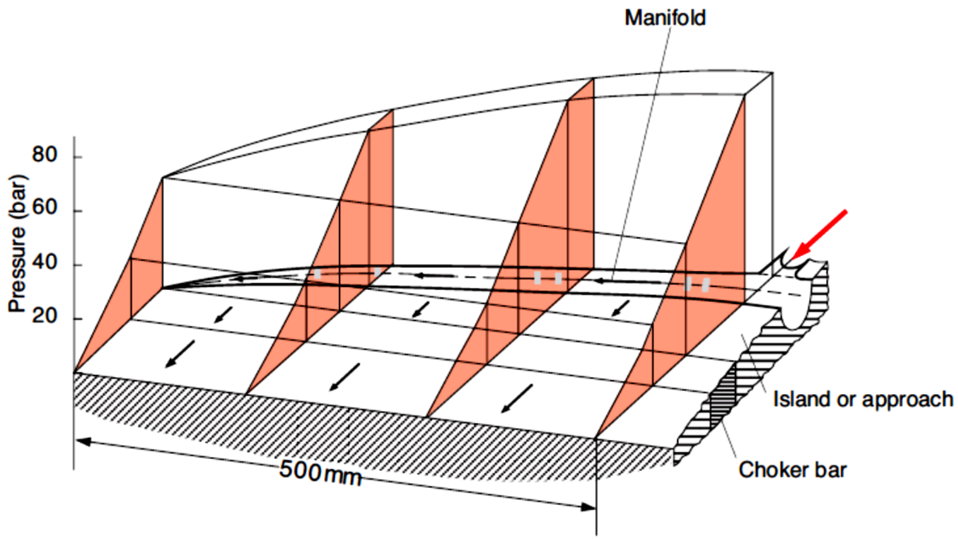


Figure 4.20 Pressure distribution in a coat-hanger die

It is important to mention that the flow through the manifold and the approach zone depend on the non-Newtonian properties of the polymer extruded. So the design of the die depends on the shear thinning behavior of the polymer. Hence, a die designed for one material does not necessarily work for another.

Tubular Dies

In a tubular die, the polymer melt exits through an annulus. These dies are used to extrude plastic pipes and tubular film. The simplest tubing die is the spider die, depicted in Fig. 4.21. Here, a symmetric mandrel is attached to the body of the die by several legs. The polymer must flow around the spider legs, causing weld lines along the pipe or film. These weld lines, visible streaks along the extruded tube, are weaker regions.

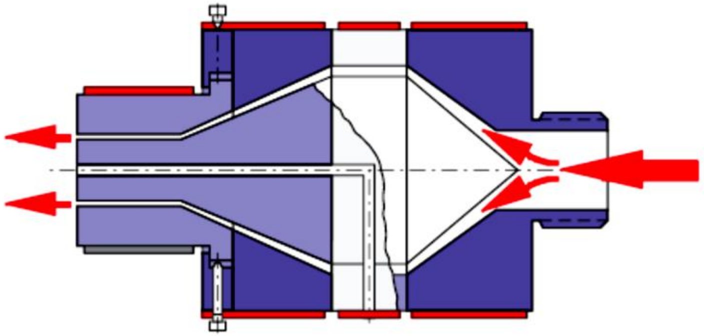


Figure 4.21 Schematic of a spider leg tubing die

To overcome weld line problems, the cross-head tubing die is often used. Here, the die design is similar to that of the coat-hanger die, but wrapped around a cylinder. This die is depicted in Fig. 4.22. Since the polymer melt must flow around the mandrel, the extruded tube exhibits one weld line. In addition, although the eccentricity of a mandrel can be controlled using adjustment screws, there is no flexibility to perform fine-tuning such as in the coat-hanger die. This can result in tubes with uneven thickness distributions.

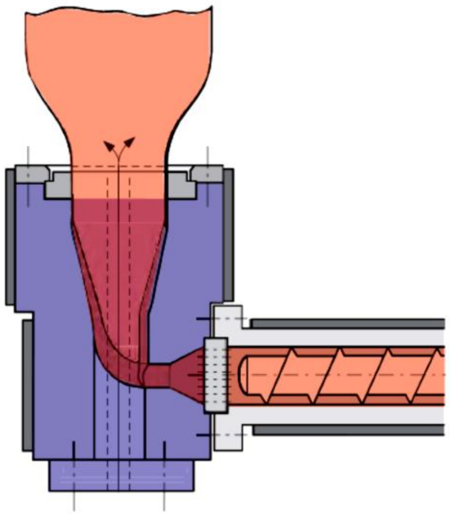


Figure 4.22 Schematic of a cross-head tubing die used in film blowing

The spiral die, commonly used to extrude tubular blown films, eliminates weld line effects and produces a thermally and geometrically homogeneous extrudate. The polymer melt in a spiral die flows through several feed ports into independent spiral channels wrapped around the circumference of the mandrel. This type of die is schematically depicted in Fig. 4.23.

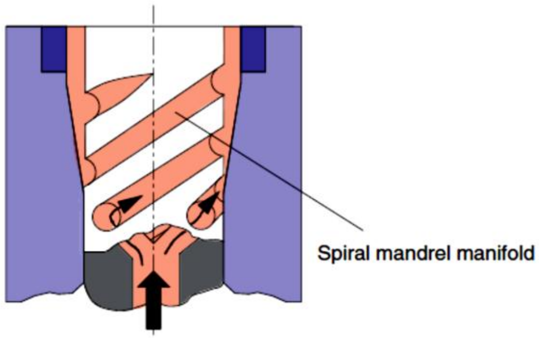


Figure 4.23 Schematic of a spiral die

The Moulds Used for Blow Moulding

Containers should always have highly polished cavities. It is therefore best to polish them once every two weeks, and certainly before they begin to oxidize. Soft paper tissue and a polishing compound should be used for polishing the cavities. A small amount of the mould polishing compound should be rubbed into each cavity, which should then be polished with a clean tissue until the cavity gives a mirror image. The tissue should be replaced constantly in order to prevent scratching while polishing. If PVC material is used, please note that PVC gas is corrosive and will attack the mould material more aggressively if proper venting is not maintained, thereby causing rapid mould deterioration.

Moulds for PE

The mould cavities used to produce PE containers should always be sandblasted, because sandblasting produces a rough mould surface, which helps proper venting. Sharp lines on the container finish indicate the need to have the cavities sandblasted. When sandblasting, extra care should be taken to protect the pinch-off edges on the parting line. After sandblasting, the mould should be completely disassembled and all cavity split vents and pin vents cleaned, and the parting line vents checked for proper depth and re-machined if necessary. The cavity pin vents or vent plugs should be cleaned every four to five weeks, because of the wax buildup on narrow passages. Improper venting of the mould will result in a poor surface finish, drop test and uneven wall thickness of the end product.

Mould Cooling Lines

Mould cooling lines should be checked for corrosion and any other obstructions that could prevent the flow of the coolant. If any corrosion is detected, the cooling lines should be cleaned immediately. The coolant liquid should also be checked to make sure that the glycol being used is compatible with aluminum, since many of the glycols will cause corrosion when used with aluminum. Reduced cooling would result in poor impact strength, deformation capacity change, and poor surface finish on the containers. In addition, it causes increased cycle time and reduced production.

Guide Pins and Bushings

These should be replaced at least once a year. However, if cycle times are increased, play is detected in mould halves, machine die locks are too loose, or pin and bushing wear is noticeable, the pins and bushings should be changed more frequently. New guide pins and bushings will improve mould life and prevent cavity and bottle mismatch.

Striker Plates and Blow Pin Plates

Striker plates and blow pin plates are vital parts of the mould, and so should be kept in good condition or replaced when necessary. Any uneven wear in the striker-plate cut-off area would produce a poor surface and flash in a neck sealing area, resulting in leaky containers.

Pinch off

Pinch-off edges are designed to cut excessive plastic from the container every time the mould is closed if bottom de-tabbers are used. However, flash in neck, handle, and shoulder areas remains on the container until its removal as a secondary operation. Worn down pinch-off edges would produce a heavy wall in the pinch-off area, causing deformed containers and difficulty in trimming. Restoring mould pinch-off edges requires specially trained tool-makers and should therefore be left to the qualified mould maker.

Shut Down

Whenever the operation is shut down for any length of time or the moulds put into storage, all waterlines should be blown out with compressed air and the cavities should be coated with a protective agent to prevent corrosion.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	

Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video links:

Plastic Injection Molding – University of Illinois: https://www.youtube.com/watch?v=RMjtmsr3CqA
Molding Machine Parts and Operation - Technology of Injection Molding: https://www.youtube.com/watch?v=DbaWBXe9-vQ
Instructional video: 80 Ton Arburg Injection Molder: https://www.youtube.com/watch?v=VxayepUk3r0
Extrusion machine process (Hindi): https://www.youtube.com/watch?v=tbsApGggYGA
Plastic Extrusion - Safety, Pre-Start and Start-Up Procedures: https://www.youtube.com/watch?v=2rzhevw2Ong
Plastic Extrusion - Operation, Shutdown and Maintenance Procedures: https://www.youtube.com/watch?v=Rf5DQR5qXxU

PLASTIC PROCESSOR

Module-9

Learner Guide

National Vocational Certificate Level 4

Version 1 - September, 2018

Extrusion Blow Molding - Lesson 3 - Extrusion Blow Molding Operating Controls: https://www.youtube.com/watch?v=YWzaZYHXS9s
Processing of Plastics- Compression and Transfer Moulding: https://www.youtube.com/watch?v=A1XKGUH7wRQ
What is Compression moulding process in hindi: https://www.youtube.com/watch?v=NlJqDPlnDXY
Compression Moulding Process: https://www.youtube.com/watch?v=sus8arkJOeA

Module 09: 072200921 Perform Shutdown Procedure

Objective of the module: The aim of this module to provide skills and knowledge to performance shutdown procedures to machine in accordance with the manufacturer's manual

Duration: 100 hours **Theory:** 20 hours **Practical:** 80 hours

Learning Unit	Learning Outcomes	Learning Elements	Duration	Materials Required	Learning Place
LU1: Arrange tools and accessories	**The trainee will be able to:** Select tools and accessories as per job requirement Verify the tools according to job requirement. Arrange material for purging as per standard Offload Mould / die as per requirement	i) Tool lifting techniques • Training of hand lifting tools • Training on machine based lifting tools • Training of cranes ii) Basic hand tools of machine maintenance and operation • Knowledge of relevant hardware and tools required for the job iii) Plastic Materials • Knowledge of which plastic materials are supposed to be cleared completely out of	**Total** 20 hours **Theory:** 04 hours **Practical:** 16 hours	Service manuals Operational manual Basic hand tools Lifting crane Moulding/extrusion machine Mould/die	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

		machines before shutting down iv) Understanding of hydraulic, pneumatic, electrical and heating system • Understanding complete wiring and lines associated with machine			
LU2: Perform planned shutdown	**The trainee will be able to:** Remove material from hopper as per requirement. Load purging material in Hopper. Set machine parameter for purging. Perform purging as requirement. Stop machine auxiliaries Stop main drives/ machine. Drain out cooling channels as requirement. Clean and lubricate Mould/ die.	i) Vacuum assisted material removing system ii) Material feed mechanism iii) Purging process iv) Initiation of Machine shutdown v) Knowledge of lubrication SOP is movable components vi)	**Total** 60 hours **Theory:** 12 hours **Practical:** 48 hours	Service manuals Operational manual Basic hand tools Lifting crane Moulding/extrusion machine Mould/die	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

	Perform low pressure clamping as per SOP. Turn off power supply of machine Report designated person as organizational procedure.				
LU3: Perform Emergency shutdown	**The trainee will be able to:** Carry out immediate emergency stop button Inform incident to designated person as SOP. Identify root cause of shutdown. Take corrective actions as per requirement. Submit shutdown report.	i) Understand safety protocols ii) Emergency shutdown SOPs iii) Incident report protocols	**Total** 40 hours **Theory:** 08 hours **Practical:** 32 hours	Machine Operational manual Emergency SOPs Incident reporting formats	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

Examples and Illustrations:

For more details please refer to these books:

1) Training in Injection Moulding, 2nd Edition, by HANSER Publishers, Munich.

2) Understanding Polymer Processing, by Hanser Publishers, Munich
3) Extrusion: The Definitive Processing Guide and Handbook by © 2005 William Andrew Publishing
4) The Dynisco Extrusion Processors Handbook 2nd Edition by John Goff and Tony Whelan, The DYNISCO Companies
5) Practical Guide to Blow Moulding Technology by Norman C. Lee, © 2006 Rapra Technology Ltd.
6) Handbook of Troubleshooting Plastics Processes by © 2012 Scrivener Publishing LLC, Chapter 18: Compression Moulding
7) Presentation on Compression Moulding, 2008 AMD 2927, IIT Delhi, by Chandra Shekhar Thakur

Shutting Down

A great deal of money can be saved by using the proper shutdown procedures. For example, if the material could be prevented from degrading or burning, a large amount of purging could be eliminated. Additional money would be saved if a complete machine shut down and cleanout were unnecessary, and start-up would certainly be easier.

Temporary Stops

It is a good idea during a temporary stop to periodically purge the cylinder or barrel by passing material through the machine and/or making air shots. If the plastic material starts to look a bit discoloured, increase the frequency of purging. When a minor machine repair is required, set the heaters on the plasticising cylinder to low values (about 150 °C) to minimise thermal degradation.

Overnight Stops

For overnight stops with thermally stable plastics such as polyethylene (PE) at blow moulding temperatures, close the gate at the base of the feed hopper and turn off the barrel heaters. With the nozzle/die heat on, purge the barrel clean by pumping the screw dry. As soon as nothing more comes from the die/nozzle, stop the screw drive and set the barrel cooling (if equipped) to maximum. When the machine is cool, shut everything off.

High Temperature Work

When extrusion blow moulding at very high temperatures (with a material that does not melt until 265 °C) oxidation and material removal can be a problem. Depending on the material type, it may be purged with a 'wet' high-density polyethylene (HDPE) (approximately 2% of water is added to the HDPE before use). The water reduces the viscosity. In condensation polymers such as polyamide and polycarbonate (PC), the water further reduces the viscosity because it causes depolymerization. Water also acts as a lubricant with polyamide. To purge, shut the gate at the base of the feed hopper and run the machine until it is free of high temperature material. With an accumulator extrusion blow moulding machine, open the die gap and keep the machine and cylinder temperatures at a high value (270 °C); run 'wet' HDPE through the system and fi ll the accumulator. The melt will foam and there will be crackling and spitting noises. Keep purging, reduce temperatures to 215 °C, and open the die gap fully. Introduce dry HDPE and then purge the barrel clean by pumping the screw dry. Turn off the heaters when no more material comes through the die, set barrel cooling to the maximum, and then when machine is cool, turn everything off. Note: a 7 kg accumulator machine may require 90 kg of ‘wet’ HDPE and 45 kg of dry HDPE to properly purge out a high temperature resin.

Heat-Sensitive Materials

A major problem with heat-sensitive materials is decomposition (‘burning’) of the plastic in the machine. The results may be discoloration and rejection of the moulded part. When decomposition occurs, a complete shutdown is usually necessary, although it may be possible to purge the heat sensitive material with another, more heat stable material to clean the machine of contaminated resin.

Purge Materials

Purge compounds are materials used to clean the cylinder (barrel) and may be purchased for this purpose. Instead of a commercial purge compound, a resin such as LDPE may also be introduced into the barrel to push out a thermally unstable material such as polyvinylchloride (PVC). Many purge materials do not melt, or flow as ordinary resins do, so to prevent blockage it is advisable to remove the die assembly before purging. The die should be thoroughly cleaned. Once the purge compound has come through, the shutdown procedure should be followed.

When PE is used as a purge, it may be stored in a small hopper alongside the main hopper, from which it can be introduced rapidly into the machine by a power-operated valve. When PVC degrades, the rapid introduction of purge material is often necessary. With a stoppage of more than 0.5 of an hour when running PVC, the barrel should be purged with PE. Stripping, cleaning and purging should be done when re-starting a PVC run after a power failure or some other unplanned shutdown.

Example: Shutting Down an Injection Blow Moulding Machine

For injection blow moulding machines, retract the barrel away from the parison meld’s sprue bushing. Run the screw dry by allowing the screw to turn just until no more melt exits the nozzle. Do not allow the screw to continue turning, because it may cause unnecessary and possibly damaging wear to the screw and barrel. Follow with a small amount of purge material, the type of which will depend on the type of material that had just been run. In the case of PE, purging is not usually necessary. It is generally safe to simply leave the screw in the forward position and turn off the barrel heats. Other materials may require different purging materials and procedures. For glycol-modified polyethylene terephthalate (PETG) (a material used to make soda bottles and many other types of beverage bottles), polystyrene (PS), low melt index HDPE, or cast acrylic are the typical purging materials. PC are generally purged with a low melt index HDPE or a cast acrylic resin. Polyetherimide resins, which are moulded at very high temperatures (in the 370-400 °C range), are purged in either a one-step or a two-step process. In the one-step process, extrusion grade HDPE (with a low melt index, in the range of 0.3 to 0.35 g/10 min) is run through the machine after as much of the resin as possible has been pumped out. The barrel temperatures are reset to the normal melt processing range for HDPE once the HDPE begins to exit the barrel. HPDE is run through the machine until the purge exiting the nozzle is clear and clean. The screw is left in its forward position inside the barrel, the heaters are turned off, and the machine is shut down. In the two-step process, a material that is intermediate in melt temperature between the high temperature material and the lower melt temperature purge material is used. For example, a PC, which normally processes in the 293 to 310 °C range may serve as an intermediate temperature material that is used for an initial purge. Once the PC begins to exit the nozzle, the barrel temperatures can be reduced to that for moulding PC. The next step is to purge the PC; either with a low melt index HDPE or a cast acrylic resin. Acrylics and PS should not be used as purge materials for resins that are processed at high temperatures, that is, at temperatures above 310 °C. Chemical purging compounds which are designed to work with certain families of materials are often used, usually in conjunction with a plastic purge material. Always check with your supervisor or team leader for the material manufacturer's recommendations regarding purging materials and the safe procedures for their use. Note: When purging materials from the injection barrel, always wear a full-face safety purge shield, always move the barrel (injection carriage) to a rearward position, never inject or purge through an open mould, and always make sure the purge safety guard is functioning and closed to avoid a serious burn accident.

Tables 8.1, 8.2 and 8.3 show some causes and effects of problems with finished containers, forming, and parisons.

Table 8.1 Finished container		
Observation	Action: Machine ***Running***	Action: Machine ***Stopped***
1. Rough surface	Check for moisture or condensation in the mould, blast with air hose and raise coolant temperature.	Additional mould venting.
2. Excessive shrinkage	Increase blow cycle. Lower melt temperature.	Check die-mandrel concentricity.
3. Warpage	Check mould cooling. Increase blow cycle. Lower melt temperature.	Same as 2
4. Weld-line breaks	Same as 3	Same as 2 Increase pinch-off areas.
5. Thin wall at parting line	Increase mould clamp pressure.	Inspect mould alignment. Inspect mould venting.

Table 8.2 Forming		
Observation	Action: Machine ***Running***	Action: Machine ***Stopped***
1. Parison blow out	Lower melt temperature. Reduce blow pressure.	Check mould for 'hot spots'. Check parison alignment. Check for contamination inside tooling.
2. Container sticking	Lower melt temperature. Lower mould coolant temperature.	Check mould design.

Table 8.3 Parison		
Observation	Action: Machine ***Running***	Action: Machine ***Stopped***
1. Excessive stretch	Lower melt temperature. Lower die temperature. Increase extrusion rate.	
2. Rough surface	Reduce extrusion rate. Raise temperature.	Clean die tip. Clean tooling. Change tooling.
3. Uneven parison	Reduce extrusion rate.	Align die and mandrel. Inspect for contamination. Inspect for heater band outage.
4. Fisheyes (bubbles)	Lower melt temperature. Lower feed section temperature.	Check resin for moisture and for contamination.
5. Streaks	Raise extrusion back pressure.	Inspect tooling for contamination or damage. Check tooling design.
6. Curl	Increase extrusion rate.	Check tooling temperature profile. Check tooling alignment.
7. Wrinkles	Lower melt temperature.	Check tooling temperature profile. Check tooling alignment.

Safe and Efficient Set-up, Start-up, Operation, Shutdown Procedures and Safety

Note: these procedures represent good practice. In an actual production environment, always follow the procedures for that particular plant.

Start-up

During the start-up of a blow moulding machine, precautions should be taken, for example: no one must stand in front of the die or nozzle and that the hopper should be firmly in place so the screw cannot be accessed. Start-up is the most hazardous time in the process because material left in the barrel from the last run can overheat and degrade, spewing hot gases and degraded plastic from the nozzle or die at high pressure. Another potential hazard is that many steps must be taken, and often quickly.

Start-Up Preparations

An understanding of the settings is needed before starting up a blow moulding machine. Obtain advice from someone who is very familiar with the equipment, or better yet, consult the written procedures. A general procedure is:

- Turn on the main power switches and then select or set the temperatures.
- Ensure that the cooling water is on and check to see that it is flowing through the feed throat.
- Preheat the hydraulic oil to its correct operating temperature. This may be done either by pumping the oil back into the tank or by using a preheater fitted for this purpose.

Once the machine has reached the required temperature, it should be allowed to settle down before any material is introduced into the barrel. The settling-in (equilibration) time, sometimes called 'soak' time, is the time needed for the barrel, screw, breaker plate, and die or mould temperatures to stabilize close to the temperature set points. The equilibration or soak time will depend on the size and type of machine. It may take 20 minutes for a small machine and it may take several hours for a larger machine. This time should be used to prepare for the production run. Other start-up steps include:

- Check the nozzle/die and molds to see if they are clean and operational.
- Review the production order for colour, quantity, and other requirements.
- Check for necessary tools and equipment and be sure they are in place and working properly.
- Make sure that all auxiliary equipment is clean and operational, to include hopper loaders, conveyors, grinders, vacuum pumps, and leak testers.

Melt Temperature

Two methods are commonly used to measure melt temperature in a blow moulding machine:

• Extrusion or injection of the material onto a suitable surface, then measuring the temperature of the plastic mass with a thermocouple probe.

• Direct reading by a thermocouple that is placed in the barrel and is in direct contact with the melt.

When the temperature of the melt is measured with a probe, care should be taken during the measurement to ensure that the purging of hot plastic does not cause an accident. As has been mentioned previously, molten material will cause serious burns because it is very hot, and it adheres to the skin and is very difficult to remove. Burns are a common injury in moulding operations, so long sleeves, gloves and face shields should be worn when handling hot material or where there is danger of being splashed with hot plastic melt, particularly during start-up or purging. As with other situations requiring personal protective equipment, the plant’s requirements must be followed.

Shutdown Procedures

It is most important to adopt a sensible shut down procedure as it can save a great deal of time and money. If, for example, the resin is prevented from burning then there will not be so much purging required on re-heating and the cost of a complete shut down and machine clean out may be saved.

After Processing a Heat-Stable Material

If a thermally stable plastic, such as polystyrene (PS) or polypropylene (PP), is being processed then, for a temporary (overnight) stop, it is usually only necessary to perform a few steps:

1. Close the slide at the base of the feed hopper 2. Turn off the cylinder heaters (leave the die heater on) 3. Purge the barrel clean by pumping the screw dry 4. When nothing more comes from the die, put any barrel cooling on maximum, stop the screw, and, when the machine is cool, turn everything off the machine is then ready for re-heating when required.

After Processing a Heat-Sensitive Material

Decomposition, or burning of polymer in the extruder barrel, may cause color changes that will result in the subsequent product being rejected. If this happens a complete shut down and clean out may be necessary. To prevent this, it may be necessary to purge a heat sensitive resin with another, more heat stable, polymer that will withstand subsequent re-heating. If material oxidation is a problem (with, say polyethylene) then it may be best to leave the cylinder full of the material rather than pumping the screw dry before switching off. Do not shut off the cooling water to the feed throat until the temperature of the first zone has fallen below the melting point of the polymer.

After High Temperature Operation

When high barrel temperatures are used, the shut down procedure should be modified to prevent thermal decomposition of the resin. One should:

1. Turn off the cylinder heaters (leave the die heater on)

2. Put any barrel cooling on maximum

3. Periodically pump resin through the machine while it is cooling, but make sure the barrel temperature remains slightly above the melting point of the resin

4. Close the slide at the base of the feed hopper and purge the barrel clean by pumping the screw dry

5. When nothing more comes from the die, and when the machine is cool, turn everything off

The machine is then ready for re-heating when required.

Display Notices

Before leaving a machine, prominent notices should be displayed if the electric supply to the machine is left on, if the heaters are on or, if parts of the machine are still hot. Water and air supplies should be turned off. The motors and pumps should be isolated so that they cannot be started accidentally.

Purging

A method of cleaning the extruder screws and barrel, without pulling the screw and disassembling the machine, is through purging. There are several reasons for purging (cleaning). One may want to change from one grade or color of material to another and/or change from one type of material to another. The net result is the same: material is wasted, and production time is lost. Therefore, the object must be to minimize such losses by careful planning of the work being done to minimize the effects of changes.

Minimizing Effects

One should try to plan production operations so that the work flows in a logical sequence. Light-colored materials should be processed first. Easy flowing (high melt flow) materials should be processed before stiff flowing (low melt flow) materials. If it is necessary when changing from one material to another, use a polymer that processes at a temperature that is intermediate between those of two widely dissimilar materials. It is very important to keep the materials handling equipment clean and to ensure contamination is not introduced during drying. The screw, barrel and die assembly must be thoroughly inspected to ensure that there are no worn or broken regions where material can stagnate, degrade, and then be released into the fresh polymer stream during production.

Temporary Stops

During a temporary stoppage the extruder may be periodically purged, by passing the material being processed through the machine at minimum screw speed. Do not allow material to build up on, or around, the die lips. If necessary, and allowable, coat the die lips with a light coat of silicone grease or other release agent. If the purged material looks discolored then increase the frequency of this purging. During a minor repair, the heaters on the barrel should be set to low values to minimize thermal degradation.

Purging Procedure

In many cases, when changing from one material to another, the barrel is simply emptied (purged or pumped dry) and the new material is then introduced into the system. In other cases (for example, when changing from polycarbonate (PC) or polyamide (PA)) a faster changeover is obtained if the barrel is purged dry and a purge material is then used. Thermoplastic materials such as polystyrene (PS), high-density polyethylene (HDPE) or cast polymethylmethacrylate (PMMA or acrylic) are widely used as purging materials. Other proprietary compounds are available for purging purposes and these should be used as directed by the manufacturer. In general, when changing from one material to another, for which the processing temperature is higher, set the barrel temperatures to those appropriate for the new material. If, however, they are lower, maintain the old temperature settings until purging is complete. Then discontinue the material supply to the hopper, empty the hopper, (carefully save the material), thoroughly clean the hopper by brushing and wiping, and replace it on the barrel (If it has been removed for cleaning). Any remaining material in the barrel should now be very soft as it has been heated (heat soaked) during the hopper cleaning. Empty the barrel into the air by rotating the screw. Introduce the new material and run a few pounds through the system as quickly as possible (that is, use the new material for cleaning or scouring). Allow the machine to stand (for approximately 10 minutes) and then rapidly run more of the new material through the barrel. Repeat this procedure until there is no sign of the old material. If it is intended to shut the system down after using a purge, the shutdown procedure may then be followed once the purge material or compound is coming through.

Purge Materials and Compounds

A purge material is a polymeric resin used for purging. It is usually a high molecular weight (high viscosity) polymeric material that is relatively stable at processing temperatures. Natural, non-flame retardant grades of polymethylmethacrylate (PMMA) or high-density polyethylene (HDPE) are often used as purge materials. A purge compound, also known as a purge, flushing compound or cleaning compound is a compound specifically designed, or used, to assist purging, or machine cleaning. It may contain large amounts of filler such as pumice. Before such purge compounds are used, it is advisable to remove the die as many purge compounds do not melt, or flow, like ordinary thermoplastic materials, and can damage the die polish or the die outlet.

Purge Compound Cleaning

If a proprietary compound is available for purging purposes then the manufacturer‘ s instructions should be followed when purging. However, if they are used correctly, such purge compounds can save considerable production time. Their use will speed up the cleaning of the barrel unit when changing from one material to another, or, from one color to another. However, in some cases, purging will not be enough to remove contamination and stripping and cleaning of the barrel unit will be required. Some purge compounds are intended for use over a specified temperature range. For example, one purge material may cover the range 180˚C to 230˚C/358˚F to 446˚F (which suits PS, PP and PMMA), another 230˚C to 250˚C/446˚F to 483˚F (which suits ABS and SAN) and another 250˚C to 310˚C/483˚F to 590˚F (which suits PC, PPO/PS and PBT).

Safety Considerations

During purging, the die area should be shielded to protect the operator from being splashed by hot material. The operator must be trained in the purging procedures appropriate to the particular machine and must be aware of the dangers to himself and others. At the processing temperatures employed, a thermoplastic material can be easily degraded to give unpleasant, irritating odors and, if seriously overheated, some materials can produce a large amount of high-pressure gas. Such gases should not be inhaled, or ingested, and should be treated as harmful. Gloves, long sleeved coveralls, safety footwear and a heat resistant face-mask should be worn during purging. Purging must be done so that there is no danger to the operator or to any others in the vicinity. The purged material should be dropped into a bucket of cold water to minimize the formation of fumes and to protect anyone from touching this hot, sticky, dangerous material.

Note Purging Conditions

During purging, the output and pressure should be noted. These values can be used to indicate screw or barrel wear. If the pressure needed to obtain a known output increases, compared to what was measured on a previous trial, then the screw, and/or barrel, may be worn and the maintenance department should be informed. During purging note if any unusual noises are heard such as might be caused by the screw and/or the screw tip rubbing against the barrel. Note the pressure employed and the output with the new material, to determine if the screw subsequently wears.

Stripping and Cleaning

In some cases, when changing from one material to another, purging is not enough, and the barrel unit must be dismantled (stripped) so that it may be cleaned. Cleaning the extruder and die is a long and time-consuming operation and, since nothing is produced, it is to be avoided if at all possible. It must be remembered that there is a danger that component damage may occur during the cleaning operation. Before commencing cleaning, the resin supplier’s literature should also be consulted since plastics behave differently when heated: PVC may decompose to give corrosive acids and PC may stick tightly to the metal of the die or extruder.

Safety Considerations

The first stage of this operation is purging and the comments made in that section should be noted. The operator must be trained in the purging procedures appropriate to a particular machine and must be aware of the dangers to him and others. When the barrel, is stripped for cleaning, it should be done in an extremely well-ventilated area. Because of this consideration, cleaning is probably best done away from the processing area. Gloves, long sleeved coveralls, safety footwear and a heat resistant, facemask should be worn when the barrel and screw are stripped and cleaned. It should always be remembered that the screw and/or die are heavy and difficult, or awkward, to handle. In many cases such components are also hot enough to cause serious burning. It must be remembered that most hot plastics, when molten, will stick to human skin, and cause destructive burns.

Partial Dismantling

In some cases, good results are obtained if the screw and barrel assembly is only partially stripped and cleaned. The die is removed, or swung to one side, and all accessible parts, including the joint faces, are cleaned. Before the screw cools, remove the screw cooling assembly from the rear of the screw (the rotary union and cooling wand), slacken any locking ring on the drive shaft and carefully extract the screw by either pushing or pulling. A “pusher”, inserted through the hollow drive shaft at the rear of the machine, can be used to drive the screw out. This slowly forces the screw out of the barrel and exposes the front of the screw for cleaning. Alternatively, if the screw is to be pulled out, the nose of the screw must be removed (usually a left-hand thread) so that a “puller” can be inserted. To strip exposed parts of the screw one may remove material by slowly pulling it away using pliers, while the adhering material is at the leathery stage. More material may then be removed by scraping. On non-chromium plated screws a steel wall paper scraper shaped to fit the channel shape may be used. The scraper may be wetted with a little cold water to minimize polymer adhesion. However, if in doubt, use brass hand tools, brass brushes and brass wool to minimize damage to the screw plating. During the cleaning operation, all exposed parts of the screw and barrel should be inspected for wear and damage. This should be noted on the machine records and, if necessary, the maintenance department informed so that appropriate action may be taken.

Heater Handling

In many cases, it is better to dismantle and clean the extruder and die. As dismantling is done while the machine is hot, heat resistant gloves and a face shield must be worn. To keep the die as hot as possible, disconnect the heaters from each zone one at a time. Ideally the power supply should be disconnected by the person who is doing the heater band removal. That is, he/she should pull the electrical plug. Remove the die heaters and thermocouples from a zone. When removing a heater, take special care not to damage it. For example, avoiding excessive flexing and careless handling. One should handle the heaters by the joint flange or terminal box and carefully store the heaters on a flat smooth surface (not the floor). All heaters and thermocouples should be labeled.

Die Cleaning

While hot, the die assembly should be carefully dismantled, taking special care not to damage metal surfaces that contact the melt. Disconnect the heaters and associated thermocouples and remove any pressure transducers, from the first part of the die that is to be removed. Then clean each piece of the die as it comes to hand. Remove as much material as possible from the die surfaces by slowly pulling it (use pliers) away while it is at the leathery stage. More material can then be removed using brass hand tools, brass brushes and brass wool. These may be wetted with a little cold water to prevent clogging. Before each part is removed, the part removed before it should be cleaned and placed on a clean smooth surface. Treat the die lips with special care as any nicks or scratches will introduce die lines, which are immediately obvious, on the product. When cleaning flat sealing faces ensure that their edges are not rounded off by the cleaning treatment. Once the components are clean, each part should be inspected for wear and damage and repaired, or replaced, where necessary. As they are cleaned, the component parts of the die should be checked off against an authorized list before being certified as being ready for use.

Re-assembly

After cleaning, the die should be re-assembled and stored either on the machine or on a bench to minimize the risk of damage. As the die is being reassembled, the alignment between the various parts of the die should be carefully checked. If these components are out of alignment, hang-up and degradation of the extrudate may occur. Also, thoroughly check the sealing faces between the die, the head, and the barrel. Unless there is adequate contact pressure on the flat sealing faces, contamination from the lubricant used on the screw threads may occur. Clean all threads with a wire brush and apply molybdenum disulfide before re-assembly. Do not use oil or grease as these may oxidize and cause a subsequent blockage. If the die is to be stored it may be treated with a rust inhibitor: Storage must be in a clean dry storeroom on a properly constructed rack. If un-plasticized polyvinyl chloride (UPVC) or another halogenated polymer has been processed, then it will probably be necessary to wash the metal with hot water to remove any traces of acid, before the die is protected with a rust inhibitor. Records must be kept of the work done on the die, where and what is stored, the tools required for maintenance and the tools required for use. Note that some dies remain the property of the customer although the extrusion firm is responsible for their use and care. If pressure transducers are installed then these must be carefully handled. Care should be taken to ensure that the correct mounting holes are used and that they are clean. If this is not done the sensing tip may be damaged, resulting in failure of the probe.

Screw Cleaning

After purging the machine with a brittle material such as polystyrene (PS) or PMMA, and when no more material can be squeezed from the screw, remove the head assembly from the extruder. Following the manufacturer‘s instructions, start to remove the screw from the barrel. If the screw can be removed in stages, the material adhering to the screw can be carefully removed with a brass scraper as each fresh portion of the screw comes from the barrel. Drop the scrapings into a bucket of cold water. When it is no longer safe to clean the screw in this way, the screw should be completely removed from the machine and placed on and strapped to a previously prepared rack. The screw may then be cleaned, by scraping with a brass scraper and a brass brush. If the screw was purged with PS, then this relatively brittle material can be easily broken away when cold. Polish the screw with brass wool and/or a brass mesh cloth until the screw is gleaming. Once the screw is clean it should be inspected for wear, and/or damage and repaired where necessary. A light coat of an anti-corrosive spray should then be applied and the screw should be placed into storage on a special rack. If the screw cannot be removed in stages then, after extracting the screw from the barrel, immediately remove as much material from the screw as possible with a brass scraper. Gently break away as much plastic material as possible when the screw is cold. If necessary, carefully reheat the screw as required. The reheat temperature should be approximately 50˚C/100˚F below the polymer’s processing temperature where the adhering material has a leathery consistency and can be removed by pulling or peeling. After removing as much material as possible, heat cleaning may be required.

Barrel Cleaning

Prior to cleaning the barrel, make sure that any pressure transducers or exposed thermocouples have been removed while the barrel is hot. Clean the barrel by pushing or pulling a hardwood bung, which is a good fit, through the barrel. Or, one may clean the barrel by pushing or pulling a circular wire-wool brush, 2 mm/0.8 in. larger than the bore diameter, through the barrel several times. Insert the wire brush into the barrel and using a power system rotate the brush while moving the brush back and forth. Periodically clean the circular wire brush and do not push the brush past the feed opening. Then wrap emery cloth (240 to 280 grade) around the brush head and polish the barrel by the same process as above.

Finally polish the barrel with a rag wrapped around the brush head until it is clean and gleaming. Then one should remove any particles, broken wires, or fragments, with a vacuum hose, and inspect the barrel for wear.

Other Cleaning Methods

Flame cleaning (with a propane gas torch) should only be used when the polymer is seriously degraded and can be removed in no other way. This is because the die parts may be distorted by uneven heating. Flame cleaning must be gently done, if it is done at all. Use the lowest temperature flame, over as large an area as practical. Do not exceed a temperature of 450˚C/842˚F on the screw flights, as the hardness and wear resistance will be diminished. After flame cleaning, clean the screw with a soft wire brush and then polish with emery cloth (approximately 240 to 280 grade). Oven cleaning, with an air atmosphere, is also best avoided as it can produce fumes and drips. The polymer may also ignite when the oven door is opened. Uniform heating, and cleaning, by pyrolytic decomposition, may be accomplished, in an oven with a nitrogen atmosphere, at temperatures in the region of 550˚C/1022˚F. If solvents are used then great care is required, as the solvent may be flammable and/or toxic. Solvent baths should be treated with respect and a written procedure followed. Ultrasonic cleaning in a heated fluidized bed is preferred for screws and dies if the equipment is available. It should be noted that copper causes rapid decomposition, or degradation, of polypropylene (PP). Therefore, copper cleaning pads should not be used to clean equipment used to process this material.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	

Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

Importance of making a check list

It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video links:

Plastic Injection Molding – University of Illinois: https://www.youtube.com/watch?v=RMjtmsr3CqA

Molding Machine Parts and Operation - Technology of Injection Molding: https://www.youtube.com/watch?v=DbaWBXe9-vQ
Instructional video: 80 Ton Arburg Injection Molder: https://www.youtube.com/watch?v=VxayepUk3r0
Extrusion machine process (Hindi): https://www.youtube.com/watch?v=tbsApGggYGA
Plastic Extrusion - Safety, Pre-Start and Start-Up Procedures: https://www.youtube.com/watch?v=2rzhevw2Ong
Plastic Extrusion - Operation, Shutdown and Maintenance Procedures: https://www.youtube.com/watch?v=Rf5DQR5qXxU
Extrusion Blow Molding - Lesson 3 - Extrusion Blow Molding Operating Controls: https://www.youtube.com/watch?v=YWzaZYHXS9s
Processing of Plastics- Compression and Transfer Moulding: https://www.youtube.com/watch?v=A1XKGUH7wRQ
What is Compression moulding process in hindi: https://www.youtube.com/watch?v=NlJqDPlnDXY
Compression Moulding Process: https://www.youtube.com/watch?v=sus8arkJOeA

PLASTIC PROCESSOR

Module-10

Learner Guide

National Vocational Certificate Level 4

Version 1 - September, 2018

Module 10: 072200922 Manage Product Quality

Objective of the module: The aim of this module to provide skills and knowledge to manage product quality, in accordance with inspection procedure, irregularities, quality acceptance, of quality control department

Duration: 120 hours **Theory:** 24 hours **Practical:** 96 hours

Learning Unit	Learning Outcomes	Learning Elements	Duration	Materials Required	Learning Place
LU1: Perform inspection	**The trainee will be able to:** Ensure calibration of inspection tools as per given standard. Inspect the sample as per requirement. Prepare reports on organizational standard formats. Follow periodic inspection as per approved standard.	i) Measuring instruments ii) Awareness of QC protocols iii) Understand and appreciate the importance of producing products as per specification iv) Be able to implement the first quality control protocol on machine to ensure elimination of defective products at sight v) Sample preparation vi) Knowledge standards (BS, ASTM, DIN, etc.) • Understand the difference in producing samples as per multiple standards vii) Testing machine operation	**Total** 30 hours **Theory:** 6 hours **Practical:** 24 hours	Measuring tools and instruments Utility documentation. Service Manuals. Operational Manuals. Basic Hand tools. Computer/ laptop for documentation (latest version with complete office automation software)	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU2: Identify irregularities as per standard	**The trainee will be able to:** Check irregularities in production as per organizational standard. Communicate irregularities in production as per	i) Maintaining product quality as per specifications • Be able to measure components for identification of dimensional defects	**Total** 30 hours **Theory:** 06 hours **Practical:** 24 hours	Measuring tools and instruments Utility documentation. Service Manuals. Operational Manuals.	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR**

	organizational standard to relevant person and authorities. Prepare reports of Ok or NOT Ok parts as per quality standard of organization.	• Usage of measurement tools is critical: Vernier caliper, micrometer gauge, scale, etc. ii) Recognize different defects and their causes • Be able to visually identify commonly occurring defects, such as eccentricity, burn lines, blistering, etc. • Gain knowledge of rectification of commonly occurring defects.		Basic Hand tools. Computer/ laptop for documentation (latest version with complete office automation software)	Visit to a training institute with relevant facilities
LU3: Apply acceptable quality level to product	**The trainee will be able to:** Take preventive action to revert to quality standard Take corrective action to revert to quality standard Record corrective/ preventive actions taken	i) Understand corrective protocols to ensure samples pass test ii) Testing standards iii) Testing Machine SOPs iv) Test report generation protocols v) Report generation protocols	**Total** 20 hours **Theory:** 04 hours **Practical:** 16 hours	Measuring tools and instruments Utility documentation. Service Manuals. Operational Manuals. Basic Hand tools. Computer/ laptop for documentation(latest version with complete office automation software)	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU4:	**The trainee will be able to:**	i) Inspection report writing • Understand the importance of reporting	**Total** 20 hours	Measuring tools and instruments	Classroom with multimedia aid and flip charts

Prepare quality inspection report	Prepare process data sheet as per organizational standard Report breakdown hours as per organizational standard	accurate production quantity • Be able to fill-in relevant inspection reports • Be able to identify waste generated along with identification of machine downtime with reasons ii) Data sharing with relevant departments • Understanding the concept of producing accurate data and benefits of the same on a larger scale • Submission of production reports to production planning department or the operations supervisor for timely actions.	**Theory:** 04 hours **Practical:** 16 hours	Utility documentation. Computer/ laptop for documentation (latest version with complete office automation software)	**EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU5: Facilitate in auditing	**The trainee will be able to:** Complete process records prior to audit as required Provide records to internal/external auditor.	i) Document preparation and file maintenance ii) Understand audit protocols	**Total** 20 hours **Theory:** 04 hours **Practical:** 16 hours	Utility documentation. Computer/ laptop for documentation (latest version with complete office automation software)	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

Examples and Illustrations:

For more details please refer to these books:

1) Training in Injection Moulding, 2nd Edition, by HANSER Publishers, Munich.
2) Understanding Polymer Processing, by Hanser Publishers, Munich
3) Extrusion: The Definitive Processing Guide and Handbook by © 2005 William Andrew Publishing
4) The Dynisco Extrusion Processors Handbook 2nd Edition by John Goff and Tony Whelan, The DYNISCO Companies
5) Practical Guide to Blow Moulding Technology by Norman C. Lee, © 2006 Rapra Technology Ltd.
6) Handbook of Troubleshooting Plastics Processes by © 2012 Scrivener Publishing LLC, Chapter 18: Compression Moulding
7) Presentation on Compression Moulding, 2008 AMD 2927, IIT Delhi, by Chandra Shekhar Thakur

Quality Control

Quality control techniques are vital to ensuring the consistency of incoming received materials, internal manufacturing processes, and outgoing manufactured products. A flow chart of a quality control methodology containing several common quality control methods is shown in Figure 13-1. The materials received by the facility for use in their manufacturing processes typically undergo acceptance sampling. If the materials do not meet specification, the lot should be rejected. As the plastics manufacturing process operates, on-line metrology of the manufactured data provides data regarding key quality attributes. This quality data can be used with a feedback controller to automatically adjust the process settings to regulate the product quality. Many plastics manufacturing systems do not use on-line metrology systems and so these elements are indicated with dashed lines.

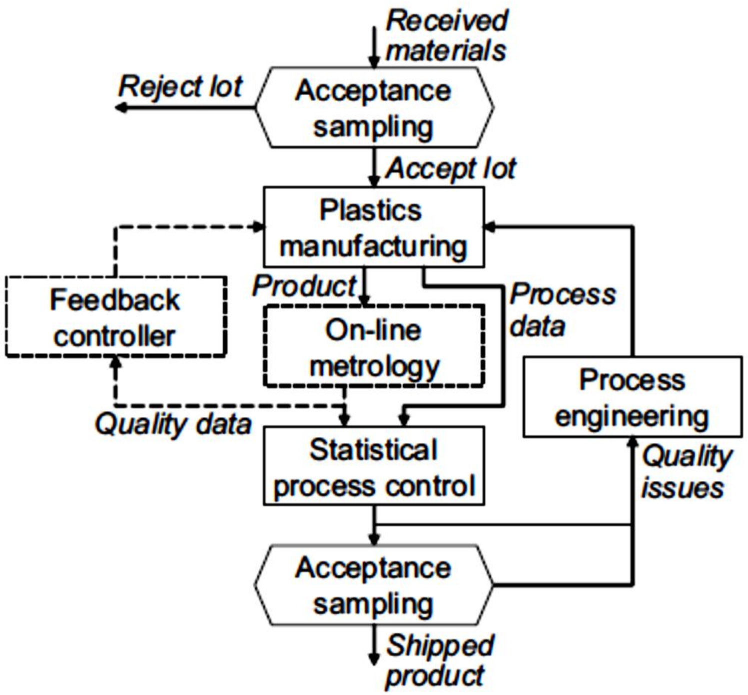


Figure 13-1: Multi-level quantity control methodology

Regardless of the use of on-line metrology, statistical process control is often applied with the process data and/or quality data to ensure process consistency. As a final check, acceptance sampling of the manufactured product can be conducted prior to shipment. If either the statistical process control or the final acceptance sampling identify quality issues, then process engineering and validation may be necessary to improve the manufacturing process. Quality control methods vary widely by the manufacturing application. Not every manufacturing facility will use these same techniques. However, acceptance sampling, on-line metrology, and statistical process control are quite common and provide a complementary basis for measuring and controlling quality. Prior to the use of any of these techniques, however, gage repeatability and reproducibility is necessary to ensure the statistical significance of whatever measurements are being taken.

Gage Repeatability & Reproducibility

The purpose of a gage repeatability and reproducibility (gage R&R) study is to determine the consistency of the measurement system. The measured product quality is the result of many factors including the material properties of the feedstock, dynamics of the manufacturing process, skill of the personnel, conditions of the environment, characteristics of the parts being measured, and the capability of the gages themselves. Given the number of potential sources for variations in quality, gage R&R studies should be performed prior to using the measurement data for process modeling, optimization, control, or product acceptance/rejection. Gage R&R is classically applied to dimensional metrology, though the concept is also applicable to other process instrumentation. In a gage R&R study, the same measurement instrument or "gage" is used by the same trained operator to measure the same dimension on the same part several times. The number of repeated measurements is typically on the order of 10 to 40. The "repeatability" of the measurement is the variation of the same measurement obtained by one operator with one gage. The operator "reproducibility" is the variation of the average measurement obtained by different operators with the same gage. Similarly, the process repeatability is the variation of the average measurement obtained by one operator with the same gage for different parts. These concepts are illustrated with the next two examples.

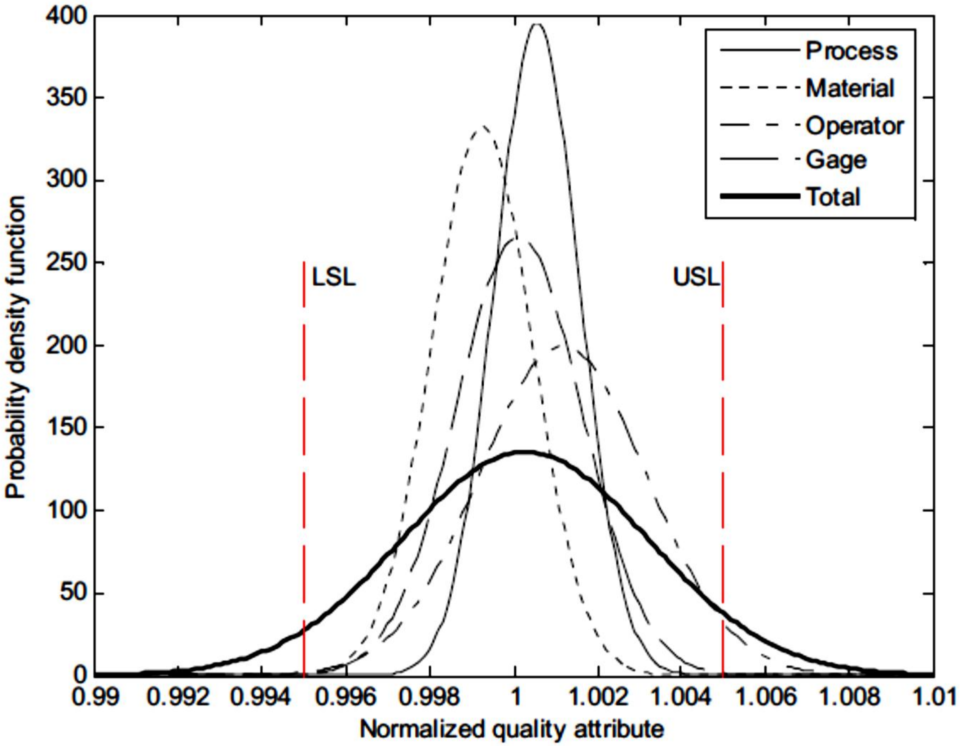


Figure 13-4: Superposition of variances

There are two key concepts of gage R&R studies that should be broadly applied to all quality control functions. First, the measurement repeatability studies are essential to quantifying the degree to which a quality attribute can be resolved. The process capability index or coefficient of variation should be calculated to compare the gage repeatability with the tolerances required in the application. To provide reasonable confidence, the gage repeatability should be significantly better, 5 and preferably 10 times, the required tolerance. Poor gage repeatability is a significant source of uncertainty in process models and will lead to poor process optimization and lower manufacturing yields. A second key concept of gage R&R is the superposition of variances from various sources. Some of the common sources of variation include the process, material, operator, and gage. Each of these sources will tend to impose its own statistical distribution as shown in Figure 13-4. In a best-case scenario, the effects will be independent and result in the broadening of the final product quality as indicated by the thick curve labeled as total in Figure 13-4. If there are interactions between sources of variation, such as between the process and the material, then the statistical variation can be much worse. The resulting propagation of variance can lead to a high defect rate even when the repeatability of the standard process is quite good. For this reason, a gage R&R study should be performed with respect to each potential source of variance. Any problematic sources of variance should then be addressed by improving the design of the plastics manufacturing system or requiring improved conformance by suppliers.

Acceptance Sampling

The science of acceptance sampling is very well developed. Schilling provides a practical review of several alternative standards from the American National Standards Institute, American Society for Quality, International Organization for Standardization, and U.S. Department of Defense military specifications. Given the depth of statistics involved and the potential breadth of sampling applications, this section provides the underlying theory and a simple method for acceptance sampling. Acceptance sampling is the intermittent inspection of a small portion of a “lot” of product. The word “lot” here means a group of products that are manufactured in a single batch under similar conditions. The quality of the entire lot is characterized from the properties of the measured samples. If the quality of the samples is acceptable, then the entire lot is accepted. If the quality of the samples is not acceptable, then the entire lot is typically rejected though some manufacturers will characterize additional samples prior to the rejection of the lot. There are two basic types of acceptance sampling typically conducted: 1) attribute sampling, and 2) variable sampling. In attribute sampling, a number of samples are tested with respect to the satisfaction of a quality attribute according to a pass/fail criterion. Some classic examples are the testing of plastic parts for physical properties by a drop impact or burst test, or for aesthetic properties such as color or black specks. In all of these tests, the attribute is rated as either pass or fail - no magnitude information about the level of the attribute is provided by the test. While these tests can be very quick, their pass/fail nature requires many samples to be tested to characterize the quality of the lot. Indeed, the number of samples can be very high especially for high quality levels. To avoid testing many samples according to a pass/fail criterion, variable sampling methods provide an alternative method in which the value of the attributes are measured and compared to the specification limits. Testing of quality attributes for variable sampling has traditionally required more time and expense than the simpler tests often conducted for attribute sampling. For example, a tensile or flexure test is more time consuming to implement than a simple drop test. However, advances in testing and metrology have made variable sampling much more amenable. For example, instrumented impact tests can now record the impact force in microsecond intervals and calculate the total impact energy impact rather than providing a simple pass/fail output. Other improved test methods are available to support variable sampling methods such as burst pressure in burst tests, color spectrum by calorimetry, dimensions by laser metrology, etc. All these tests provide a value of the quality attribute being measured; gage R&R studies can be applied to verify the gage repeatability relative to the required attribute tolerances.

Variable sampling methods are recommended here given the reduced number of samples required to provide the same confidence level compared to acceptance sampling methods. The number of samples to be tested, n, is a function of the lot size, the acceptable quality level (AQL), and the application inspection level. The acceptable quality level indicates the percentage of defects that the sampling plan will accept 95% of the time; smaller AQL values require more stringent acceptance sampling plans to assure lower defects in the lot. The inspection level can be specified by either the customer or the manufacturer according to the cost of the product, criticality of the application, and cost of the product failure in end-use. The most common inspection levels are normal and military specification (“mil-spec”). Given the acceptable quality level, inspection level, and lot size, the number of samples to test is specified by standards such as MIL-STD-414 titled “Sampling Procedures and Tables for Inspection by Variables for Percent Defective. Table 13-3 provides a subset of this specification, listing the number of samples, n, for normal and mil-spec inspection levels, AQLs of 0.1 to 10%, and lot sizes from 10 to 100,000. It is observed that as the lot size increases, the number of samples to test must increase to prove assurance that the tested samples are indicative of the entire lot. It is also observed that the mil-spec inspection level is more stringent, usually requiring more samples to be tested.

Table 13-3: Sampling Plan Requirements

		Inspection level			
		Normal		Mil-Spec	
AQL	Lot size	*n*	$k_{critical}$	*n*	$k_{critical}$
10%	10	3	0.57	3	0.57
10%	100	3	0.57	10	0.83
10%	1,000	10	0.76	35	0.97
10%	10,000	30	0.95	75	1.03
10%	100,000	35	0.97	200	1.07
1%	10	4	1.45	4	1.45
1%	100	4	1.45	10	1.72
1%	1,000	10	1.62	35	1.89
1%	10,000	30	1.86	75	1.98
1%	100,000	35	1.89	200	2.04
0.1%	10	10	2.42	10	2.42
0.1%	100	10	2.42	10	2.42
0.1%	1,000	10	2.42	35	2.54
0.1%	10,000	30	2.51	75	2.66
0.1%	100,000	35	2.54	200	2.73

As the acceptable quality level becomes more stringent, the number of samples to test in Table 13-3 does not change much. Instead, the value of $K_{critical}$ increases significantly. The variable k represents the number of standard deviations, σ, of sample variation between the sample mean, μ, and the closest specification limit:

$$k = \min\left[\frac{\mu - LSL}{\sigma}, \frac{USL - \mu}{\sigma}\right] > k_{\text{critical}}$$

where LSL and USL represent the lower and upper specification limit. If k is greater than the critical value, $K_{critical}$, then the lot is accepted otherwise the lot is rejected. The concept of increasing the critical value is illustrated in Figure 13-5. In this figure, the mean, μ, is 1.0, the standard deviation, σ, is 0.002, and the upper specification limit, USL, is 1.004. Suppose that a 1,000 quantity lot is to be sampled at a normal inspection level. Ten parts are sampled regardless of the specified AQL. However, the critical number of standard deviations, $K_{critical}$, is 0.76 for an AQL of 10%, 1.62 for an AQL of 1%, and 2.42 for an AQL of 0.1%. As shown in Figure 13-5, increasing the value of $K_{critical}$ has the effect of artificially tightening the specification limits. The lot is accepted based on the tested samples as long as the sample mean is less than the tightened specification limit. In this case, the lot would be accepted for acceptable quality levels of 10% and 1% but rejected for an AQL of 0.1%.

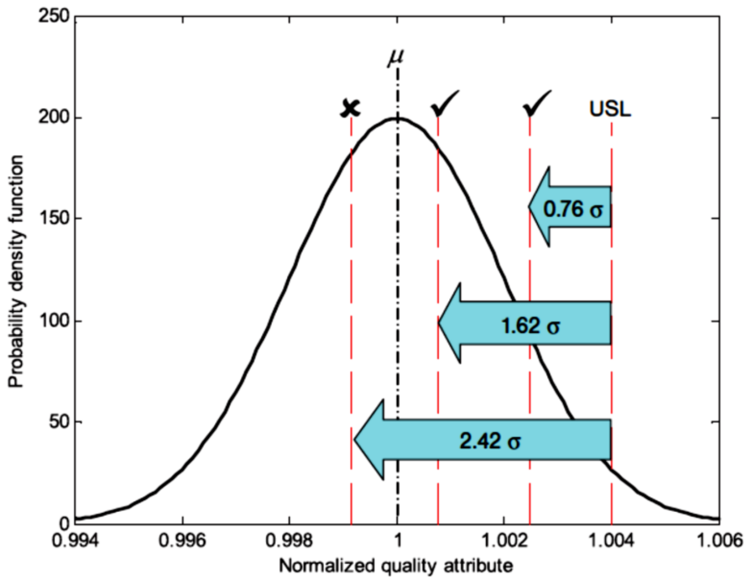


Figure 13-5: Tightening of constraint in acceptance sampling

On-Line Metrology

The primary benefit of acceptance sampling is the reduction in the number of components that must be measured to estimate the quality of a lot of manufactured products. However, acceptance sampling has some significant issues. First, acceptance sampling requires dedicated human and metrology resources with intermittent planning, execution, and storage of results. Second, acceptance sampling affords the possibility of accepting defective lots as well as rejecting acceptable lots. Both of these errors can result in very major costs. Acceptance of defective lots is a particularly significant concern given the loss of customer goodwill, expense of warranty claims, and potential personal injury claims in some applications. Because of these issues with acceptance sampling, some regulatory agencies such as the Food and Drug Administration require 100% inspection in critical applications. Many manufacturers also prefer to avoid acceptance sampling by using 100% inspection methods.

While operators could inspect every part, their performance is limited by cost, fatigue, and reliability. As such, 100% inspection in high volume applications may be best served with plastics manufacturing systems that integrate on-line metrology of every manufactured product. Some of the more common on-line metrology systems include rheometry, machine vision, laser metrology, structural tests, and a variety of poka-yoke techniques.

Dimensional Metrology

Dimensional metrology has historically been conducted in quality assurance laboratories using coordinate measurement machines and more recently with laser scanning and stereoscopic vision. However, these off-line techniques are poorly suited to 100% inspection in plastics manufacturing given the volume of product to be tested and cost of the metrology. These issues are further compounded by the fact that the size of the plastic products may change over time with further cooling and annealing. As such, significant variances can be induced into the dimensional measurements just by time differences associated with the scheduling of the metrology after the parts. For this reason, dimensional metrology can be implemented on-line through the use of appropriate laser micrometers, photodetectors, ultrasonic gages, or machine vision. An extrudate measurement application is provided in Figure 13-7.

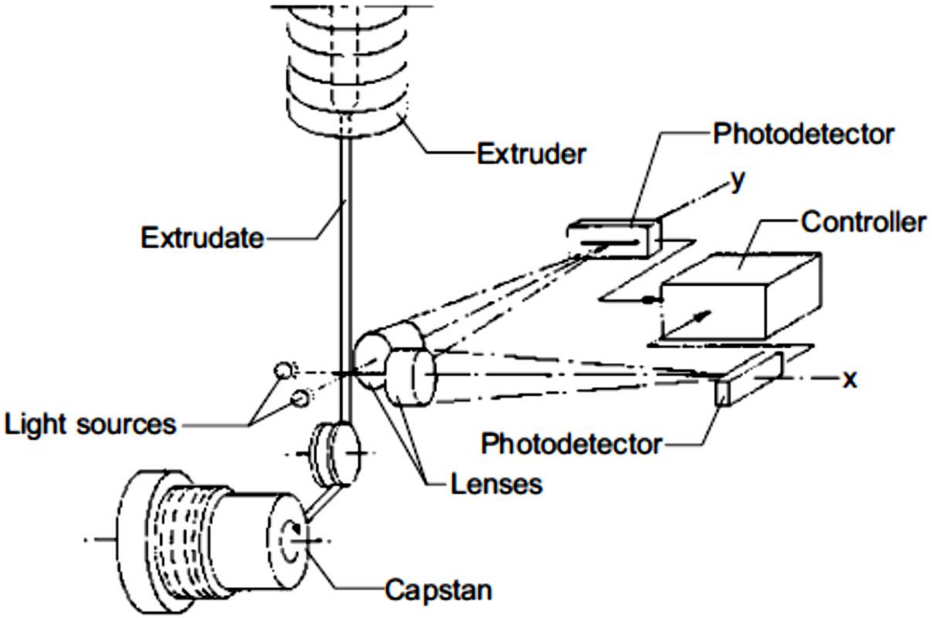


Figure 13-7: On-line dimensional metrology of extrudate

In this design, two light emitting diodes provide a light source parallel to the x- and y-axes. Each measurement axis is provided a light source and corresponding photodetector to measure the width of the shadow cast by the extrudate. Laser micrometers have a similar layout with respect to the extrudate but provide the light source by scanning the laser across the extrudate using a moving mirror. Both laser micrometers and photodetectors typically provide more than 1,000 samples per second with a resolution below 10 μ m.

Another common type of on-line dimensional metrology is thickness measurement by ultrasonic attenuation or optical absorption methods. The design and operation of an ultrasound gage for measuring thickness is shown in Figure 13-8. In this system, an ultrasonic transducer intermittently transmits an ultrasonic pulse with a frequency of 5 MHz into the part. As the pulse reaches each of the various layers, a signal will be reflected due to the variations in the acoustic properties. Given the speed of sound in the polymer, the thickness hi of each of the layers can be computed from the time delays of the received reflections.

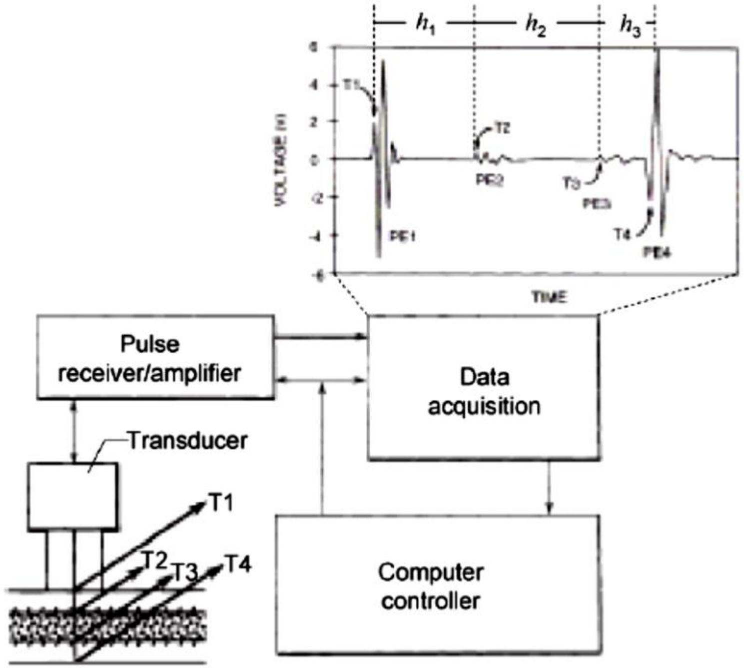


Figure 13-8: On-line ultrasound thickness measurement

The design of Figure 13-8 is directed to multi-layer extrusion. The performance of the method is limited by the sharpness of the gradient in the material properties between the various layers. If the layers have a broad melting zone, then the acoustic property gradient and the resulting reflected signals will have a much lower signal to noise ratio. However, the technique is well suited to multi-layer blow molding and extrusion as well as thickness measurement of monolayer parts as from conventional injection molding. There are two issues that should be understood in application. First, the ultrasonic measurement requires momentary contact between transducer and the target, so the measurement is best taken with the product in a solid state. Second, the accuracy is related directly to the speed of sound in the target material. The speed of sound varies from 2060 m/s for PS, to 2390 m/s for PVC, to 2690 m/s for PMMA, and is temperature dependent. For these reasons, plastics manufacturing systems relying on ultrasonic measurements should perform application-specific calibration and validation; accuracy will vary widely by application but is in the vicinity of 0.02 mm. There are alternatives to ultrasonic thickness measurement for on-line metrology. One increasingly common method is optical attenuation. The design and operation is very similar to that shown in Figure 13-8 albeit with a signal frequency in the visible spectrum. The primary advantage of optical systems is that they do not require contact with the target, which can be important in very high rate manufacturing applications. However, optical methods are only applicable to transparent polymers and the accuracy is again limited by the precision of the optical transparency of the material. Precision is typically on the order of 0.02 mm though interferometry-based methods can provide precision of 1 μm.

A third alternative for thickness measurement is based on the Hall effect. In this method, the sensor probe applies a magnetic field across the thickness of the part that interacts with a ferrous target on the opposite side. Since the geometry of the ball is known, the thickness of the part can be ascertained by measuring the resulting current associated with the strength of the magnetic field. The primary advantage of Hall effect gages is that they are mostly independent of the material properties of the plastics. Unfortunately, Hall effect gages require not only contact of the probe and steel target on opposing sides of the part but careful alignment of the probe and target as well. Due to this disadvantage, Hall effect gages are rarely used on-line.

Machine Vision

Machine vision is the process of automatically extracting information from visual sensors to provide determination of machine control actions. In the most successful applications, machine vision systems are developed to perform specific tasks such as verifying the existence of parts, counting number of parts on a conveyor or being ejection from a mold, measuring color or reflectance, checking for contamination, and measuring the part orientation and dimensions.

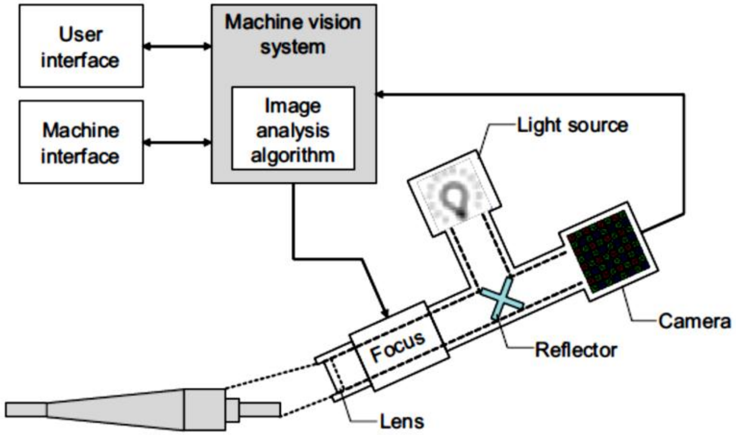


Figure 13-9: Machine vision system

One machine vision system is shown in Figure 13-9. The vision instrumentation includes a camera, light source, and other elements for adjusting the focus. The light source can be provided internal to the vision system to improve system robustness and reduce maintenance. A focus mechanism, often including piezoelectric actuators, is used to adjust the lens distance prior to image capture. The focus control is provided by the machine vision system using an image analysis algorithm with real time feedback from the camera. The machine vision system can have bidirectional communication with the machine controller. The machine controller will typically provide a signal specifying when the image should be acquired and in return receives a signal determining what control action should be taken. The machine vision system will typically have a user interface for setting the parameters used in the image analysis as well as displaying the acquired images.

The performance of the system can be limited by the resolution and response time of the camera, which in turn are limited by the bandwidth of the camera's image sensor and processor. A trade-off is usually made between a high resolution and high speed. For instance, a high-resolution camera may provide one static image per second with a resolution of ten thousand pixels in the horizontal and vertical dimensions while a high-speed camera may provide ten thousand frames per second with a resolution of 1000 by 1000 pixels. In both cases, the bandwidth of the imaged data is one hundred million pixels per second. The camera specification should be derived from the application requirements including the production rate, measurement tolerances, and cost constraints.

Weight

Part weight is a widely used estimator of part quality since this measurement poses several advantages. Given that the part weight is found to have very high correlation to the material density and the part dimensions, part weight variation is often readily detectable if either the material or process is inconsistent. In addition, the part weight can be measured immediately after production of the plastic part while other part properties, such as the dimensions or strength, are typically evaluated after the part has equilibrated to room temperature. Finally, the accuracy of part weight measurement has a coefficient of variation, COV = σ/μ, on the order of 0.01%, which often exceeds that of other quality measurements.

There are a few common issues with part weight measurements. First, the part weight is an aggregate measure of the total material content in the part; the part weight does not provide any information about the distribution of the material across the part. The material distribution can vary significantly in blow molding and thermoforming process and can be problematic as a quality estimator in tight tolerance injection molding and extrusion applications. Second, the part weight can vary significantly with moisture absorption in hydrophilic materials. This property can complicate the use of part weight for quality control unless the environment and timing of the measurement are controlled. Third, accurate part weight measurements are sensitive to air pressure acting on the measurement plate and so require the use of a windshield to block local air currents. Fourth, the brief delay required to take a weight reading can be problematic in plastics manufacturing systems with very high production rates. Given these potential issues, two approaches for rapid and accurate part weight measurement are next presented.

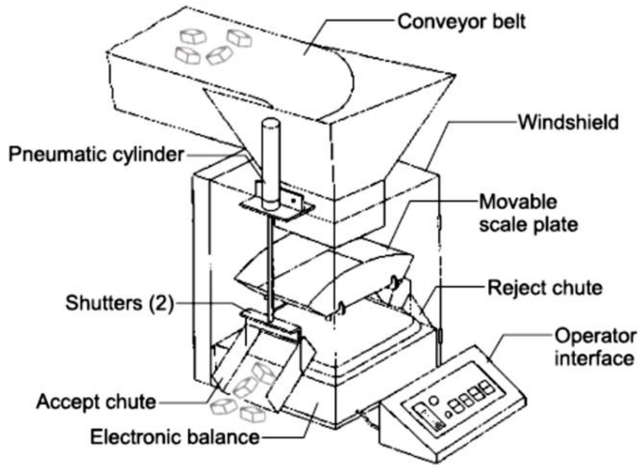


Figure 13-11: On-line weight checker

One approach to on-line measurement of part weight for injection molding is shown in Figure 13-11. In this system, the parts are fed by conveyor belt to a weighing station enclosed within a windshield. Dropping the parts directly onto the scale's measurement plate could result in damage to the scale. As such, a movable plate is positioned above the scale and used to receive the plastic parts. The end of the molding cycle, speed of the conveyor, and timing of the weighing station's pneumatic cylinder are synchronized so that the movable plate is actuated after a cycle's parts are collected. The scale weighs the sample, subtracts the mass of the movable plate, and determines the acceptability of the parts by comparing the measured weight to a range specified by the operator. The appropriate shutter is then opened, and the movable plate is tilted to pour the parts down the appropriate accept/reject chute. While the scale eliminates the need for an operator to measure the part weights, coordination of the measurement system with the plastics manufacturing process can become problematic in very high rate applications where individual part weight measurements are desired. An alternative approach is conveyance-based part weight measurement as shown in Figure 13-12.

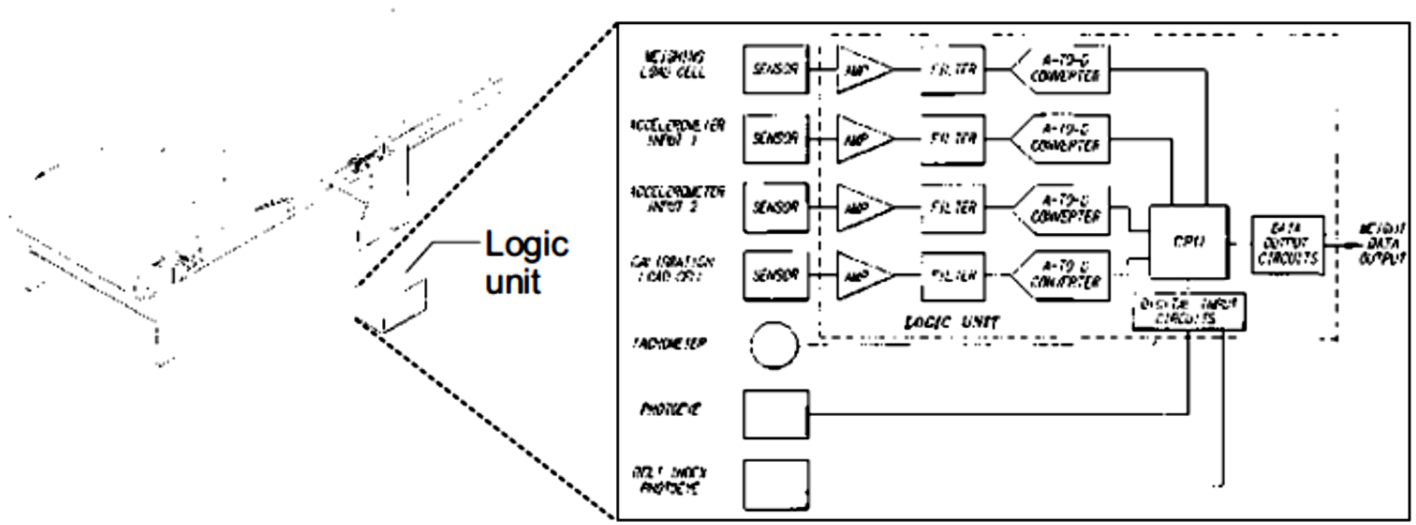


Figure 13-12: Conveyance-based weight measurement

In this system, products are conveyed one at a time across the conveyor. The conveyor has an internal tensioning system to keep the conveyor belt taught under a variety of loads. Part weight measurement based on the state of the tensioning system have tended to provide inaccurate results given the movement and oscillation of the tensioning components. In this design, however, accelerometers are used in combination with load cells to deduce the part weight even as the part is loaded onto the conveyor and the tensioning system is stabilizing. As such, part weights can be taken continuously at high speed. The concept of coupling accelerometers with load cells for rapid part weight measurements is still in its infancy. However, one should expect that this approach will be integrated with other material handling systems, such as robot end effectors, part storage racks, and mold ejection systems to inexpensively but accurately monitor the weight of the manufactured plastic products.

Importance of using PPEs

PPE is equipment that will protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

PPEs:

Name & Usage	Picture of PPE	Name & Usage	Picture of PPE
Safety goggles – used to protect eyes from flying particles (chips, sparks etc.)		Safety shoes – used to protect feet from spatters of welding and impact of other falling objects	
Face shield - used to protect face from welding sparks, radiations, arc and spatters		Face mask – used to protect from inhaling fumes, dangerous gases etc.	
Hard cap – used to protect the head from injury due to falling objects		Leather Apron – used to protect welder's body from welding spark and spatters	
Leather gloves – used to protect hands during welding		Cotton gloves – used to protect hands from sharp edges of sheets and plates	

Importance of housekeeping and safe storage of tools and equipment

The main function of housekeeping is to ensure cleanliness, comfort, convenience, privacy, health and hygiene in a safe environment. It includes keeping work areas neat and orderly. All the tools and equipment must be stored properly.

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It ensures you get your daily, weekly and monthly tasks done on time, helps you keep track of projects on deadline and ensures you're organized throughout the day.

Video links:

Plastic Injection Molding – University of Illinois: https://www.youtube.com/watch?v=RMjtmsr3CqA
Molding Machine Parts and Operation - Technology of Injection Molding: https://www.youtube.com/watch?v=DbaWBXe9-vQ
Instructional video: 80 Ton Arburg Injection Molder: https://www.youtube.com/watch?v=VxayepUk3r0
Extrusion machine process (Hindi): https://www.youtube.com/watch?v=tbsApGggYGA
Plastic Extrusion - Safety, Pre-Start and Start-Up Procedures: https://www.youtube.com/watch?v=2rzhevw2Ong
Plastic Extrusion - Operation, Shutdown and Maintenance Procedures: https://www.youtube.com/watch?v=Rf5DQR5qXxU
Extrusion Blow Molding - Lesson 3 - Extrusion Blow Molding Operating Controls: https://www.youtube.com/watch?v=YWzaZYHXS9s
Processing of Plastics- Compression and Transfer Moulding: https://www.youtube.com/watch?v=A1XKGUH7wRQ
What is Compression moulding process in hindi: https://www.youtube.com/watch?v=NlJqDPlnDXY
Compression Moulding Process: https://www.youtube.com/watch?v=sus8arkJOeA

PLASTIC PROCESSOR

Module-11

Learner Guide

National Vocational Certificate Level 4

Version 1 - September, 2018

Module 11: 072200923 Manage Production Flow

Objective of the module: The aim of this module to provide skills and knowledge to manage production flow of machine in accordance with the manufacturer's manual

Duration: 100 hours Theory: 20 hours Practical: 80 hours

Learning Unit	Learning Outcomes	Learning Elements	Duration	Materials Required	Learning Place
LU1: Plan production schedule	**The trainee will be able to:** Verify Job card Distribute plans on shop floor Ensure workforce according to production target	i) Understand job card ii) Machine capacity iii) Selection of suitable operator with respect to operational skills iv) Employee Utilization Rate – The percentage of time during which a staff member is actively working versus the number of work hours expected for work v) The optimal amount of time required to generate a single item vi) Inventory Turnover – A ratio that indicates how many instances a firm's inventory is sold and refurbished over a determined time period, which can be measured by dividing the total sales by number of inventory or by dividing the value of products sold (COGS) by average number of inventory available during a specified	**Total** 30 hours **Theory:** 06 hours **Practical:** 24 hours	Utility documentation. Service Manuals. Operational Manuals	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

		selling period (monthly, quarterly, yearly) vii) Capacity Utilization Rate – The percentage of the actual manufacturing yield versus the possible manufacturing yield			
LU2: Ensure raw material & accessories	**The trainee will be able to:** Verify the types of material Arrange the master batch or pigment Arrange the packaging material	i) Material identification ii) Material additives iii) Pigment and dies iv) Product packaging	**Total** 30 hours **Theory:** 06 hours **Practical:** 24 hours	Utility documentation. Service Manuals. Operational Manuals	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU3: Ensure machine datasheet	**The trainee will be able to:** Feed new setting Verify from PD &QC+QA Arrange reference sheet	i) Machine setup operation ii) Coordination with QC & QA deptt. iii) Measures to improve production methods, equipment performance	**Total** 20 hours **Theory:** 04 hours **Practical:** 16 hours	Utility documentation. Service Manuals. Operational Manuals Machine	Classroom with multimedia aid and flip charts **EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities
LU4: Prepare production report	**The trainee will be able to:** Select the target	i) Compiles, stores, and retrieves production data.	**Total** 20 hours **Theory:**	Utility documentation. Reporting formats	Classroom with multimedia aid and flip charts

	Make hourly production report Feed the actual production with plan	ii) Write production and operating reports and resolve operational, manufacturing, and maintenance problems to ensure minimum costs and prevent operational delays.	04 hours **Practical:** 16 hours		**EITHER** Visit to Plastic Processing Facilities **OR** Visit to a training institute with relevant facilities

Examples and Illustrations:

For more details please refer to these books:

1) Training in Injection Moulding, 2nd Edition, by HANSER Publishers, Munich.
2) Understanding Polymer Processing, by Hanser Publishers, Munich
3) Extrusion: The Definitive Processing Guide and Handbook by © 2005 William Andrew Publishing
4) The Dynisco Extrusion Processors Handbook 2nd Edition by John Goff and Tony Whelan, The DYNISCO Companies
5) Practical Guide to Blow Moulding Technology by Norman C. Lee, © 2006 Rapra Technology Ltd.
6) Handbook of Troubleshooting Plastics Processes by © 2012 Scrivener Publishing LLC, Chapter 18: Compression Moulding
7) Presentation on Compression Moulding, 2008 AMD 2927, IIT Delhi, by Chandra Shekhar Thakur

Process Optimization

The productivity of plastics manufacturing systems is jointly determined by the design and operation of the processing machinery. In many if not most processing applications, the cost or quality of the manufactured products can be reduced without any physical change to the machine design. The suggested optimization methodology is shown in Figure 12-1. Given these models, the capability of the process is assessed to estimate the potential yield of the process given specifications on the product quality. If the process has potential, then the process optimization continues. The feasible operating region, often referred to as the “process window”, can be mapped from the developed process models. Given identification of the dominating constraints, optimization techniques can be applied to explicitly chart the trade-off between product quality and manufacturing costs, often referred to as the Pareto optimal boundary or “efficient frontier”. The process engineer can then determine the single best operating point for the process or redesign the process to further improve the quality or reduce costs.

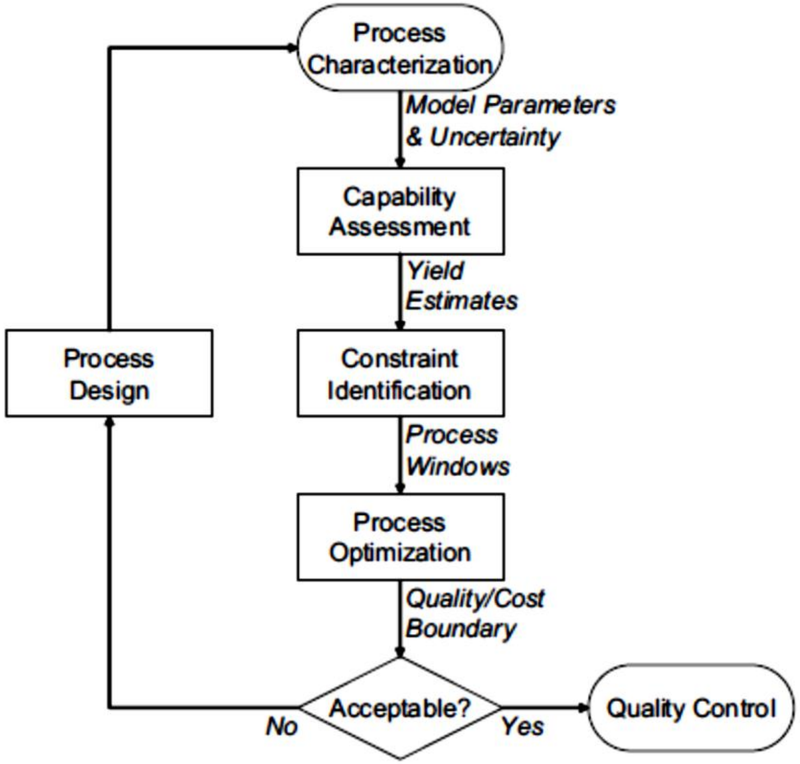

Figure 12-1: Process optimization methodology

Process Capability Assessment

Given that all manufacturing processes exhibit variation, the capability of the process is usually assessed relative to specification limits. There are several common methods used to assess process capability, most of which assume normal statistics. The underlying framework for these process capability assessments is provided in Figure 12-2. In considering the process capability, the distribution of the process data is considered relative to the lower specification limit, LSL, and the upper specification limit, USL. If a normal distribution is assumed with a mean, μ, and a standard deviation, σ, then the percentage of manufactured defects can be readily calculated along with the yield of acceptable product. Several other process capability measures are common in the manufacturing industry, including the process capability index, defects per million opportunity, and process capability roll-up. Each of these measures is next discussed.

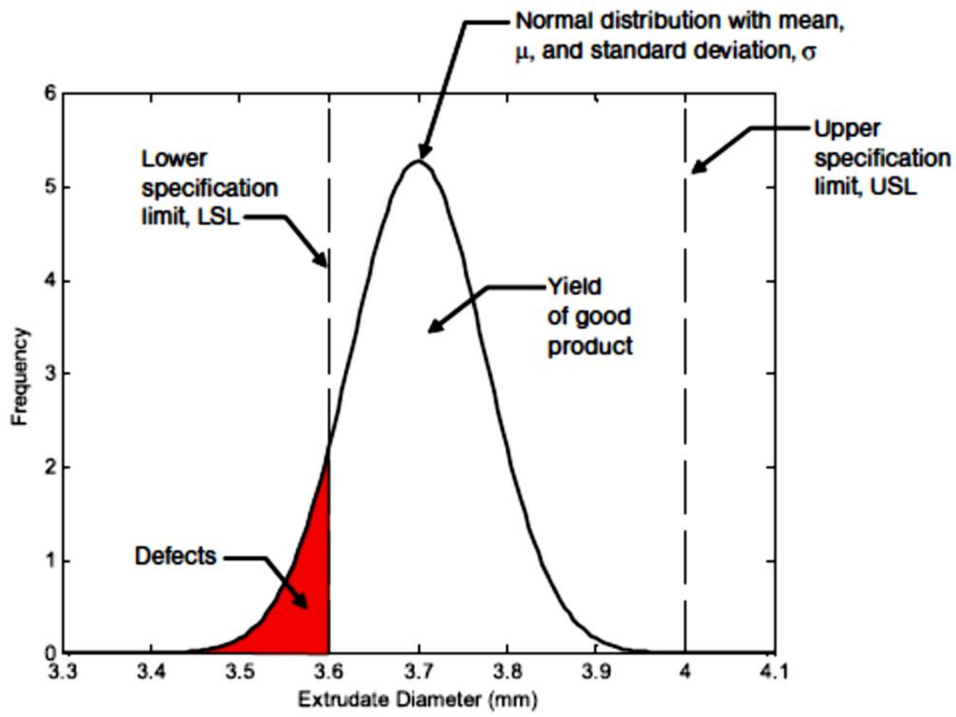

Figure 12-2: Process distribution relative to specifications

Six Sigma

"Six Sigma" is a quality control initiative developed by Motorola that increasingly refers to corporate initiatives with multiple objectives and a broad range content generally directed to corporate competitiveness. However, the most fundamental tenet of Six Sigma, from which the name is derived, is that six standard deviations of process variation should be maintained between the process mean and the closest specification limit. As shown in Figure 12-3, LSL and USL correspond to the lower and upper specification limit on a critical quality attribute while μ and σ represent the observed mean and standard deviation. Statistically, only two defects per million opportunities (DPMO) would occur if the six sigma criterion was satisfied.

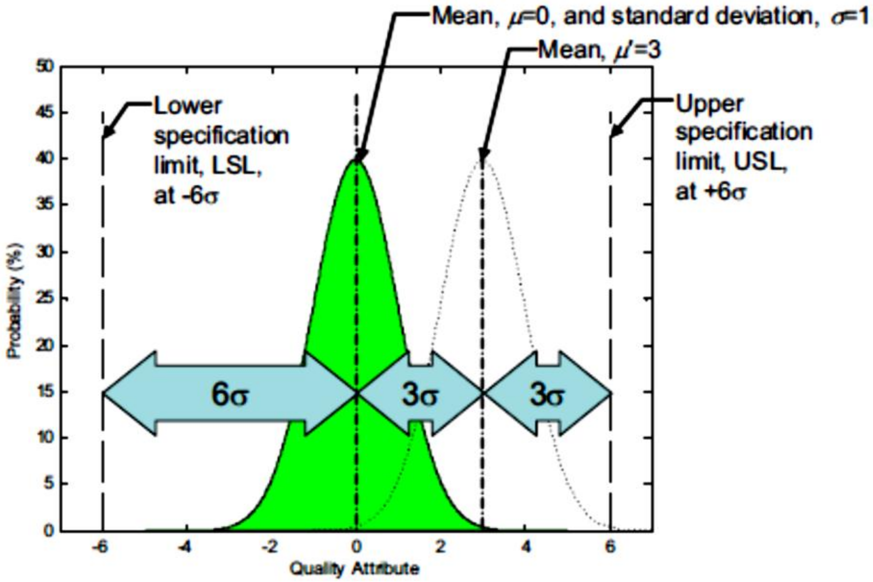

Figure 12-3: Six sigma concept

Historically, there are two somewhat different motivations for achieving Six Sigma. First, it has been argued that Six Sigma is necessary in large systems, such as semiconductors, that internally contain many opportunities for defects. Since the system may fail with any given component, reliability theory states that the DPMO must be extremely low to achieve reasonable yields in production, typically greater than 95%. An alternate motivation in Six Sigma pertains to the product development process and ensuring long term stability in the product quality. With six standard deviations between the process mean and the closest specification limit, a long-term shift of three standard deviations in the process mean from μ to μ′ can occur while still ensuring three sigma for short term, random variation as shown in Figure 12-3. As such, a 99.7% yield should be achieved in 99. 7% of applications exhibiting 3σ short term variability. Since its inception, Six Sigma has drawn upon many previously established methodologies including the design, measure, analyze, improve, control (DMAIC) process. Another significant underpinning of Six Sigma is the capability roll-up for manufacturing processes that have multiple specifications. In a capability roll-up, the defects per million opportunity are individually calculated for each specification according to the previously defined normal statistics. The defects per million are then summed to provide the total number of defects expected per million opportunities, DPMO. These calculations for the total DPMO are expressed by the equation:

$$DPMO = \sum_{i=1}^{m} 1 \cdot 10^6 \cdot \left[1 - \mathrm{erf}\left(\frac{3 \cdot C_{P,i}}{\sqrt{2}}\right)\right]$$

where $C_{P,i}$ is the process capability associated for the i-th of m specifications. After the total DPMO is calculated, the yield can be estimated as:

$$\text{yield} = \left(1 - \frac{DPMO}{1 \cdot 10^6}\right)$$

The rolled-up process capability index can also be calculated as:

$$\bar{C}_P = \frac{\sqrt{2}}{3} \mathrm{erf}^{-1}(\text{yield})$$

For a process to qualify as six sigma, the rolled up process capability index must be two or greater.

Six sigma is a powerful methodology, but rarely reduces rates to only a few defects per million even when the process capability index exceeds two. One primary reason is that most processes are not truly normally distributed, but rather possess wider statistical distributions than characterized with short to mid-term processes. A second significant reason is that discrete events, such as due to human error, can result in the production of a few hundred defects that could consume the entire allocation of defects in a six sigma facility for decades or centuries of production [279].

In reality, then, the two primary objectives of Six Sigma are to:

1. minimize the process variation, and
2. move the process away from the closest specification limits to maximize the yield.

Minimizing the process variation can best be accomplished by good machine, instrumentation, and control systems design, though some applications may exhibit lower variation in some regions of the process. As such, process engineering often and rightly focuses on keeping the process away from the closest specification limit.

Example: Managing Production Flow of Blow Moulding Process

First, lay out the entire process, step-by-step. What has to be done, when, and where? Whenever possible, finish the part to the maximum degree possible, possibly even to include packaging, in the moulding room and adjacent to the blow moulding machine. Doing this promises the best economics as it eliminates the labour involved in warehousing, transport, and storage. An additional benefit is that quality problems can be quickly communicated back to the moulding department. A common problem in blow moulding plants is moving parts to separate finishing departments which work on completely different schedules or only on day shift, while moulding is often an around the clock, 24/7 operation. Careful planning and an efficient plant layout are required when designing for:

Labelling

- Decorating, e.g., labelling and hot stamping
- Drilled holes:

- In compression moulded areas, consider punching in-mould.

- In blown areas, consider a 'bubble' which can be 'snare cut', rather than drilled chipless!

- Threads:

- Internal threads can be formed by using unscrewing cores.

- External threads can be formed by threaded cavity sections that are split along parting lines.

- De-flashing:

- In entirety.

- Partial, in stages.

More specific considerations should include:

1. Investigate making the flash productive during its limited life. Can it be configured to serve as a temporary handling, positioning or registration device?

2. Part handling – removal:

- Automatic – preferred, enables 'gate closed' consistent operation:

- Stripper 'pop and drop',

- Via side takeout,

- Via bottom takeout.

- Manual - operator controlled.

Unless the operator is exceptional, the cycle time in some operations can vary from shot to shot, creating inconsistencies in thermal history, which leads to shot-to-shot variation in product weight, location of programming points, and dimensional variations. This is demonstrated by the readily visible symptom of variation in the tail length, and overall parison length. The operator will say that 'those tails keep changing on me'. Actually, the operator is changing the tail length by running an inconsistent cycle.

3. Part handling - secondary cooling:

- Parts up to 2.3 mm thick, if moulded in a well-cooled mould with reasonably designed flash pockets, should not require secondary cooling.
- Medium wall parts are sometimes conveyed by a fan, which is also used for cooling.
- Heavy wall parts – 9.52 mm and heavier – may be passed through chilled water spray, or conveyed through a chilled water bath.
- Having to hold the parts until they cool, prior to deflashing, is more often than not due to the retained heat in the flash. Deflashing early, rather than later, minimises the hazard of the retained heat migrating back into the part, which, in turn increases the possibility of warpage.

4. Parts handling – warp control or shrink fixturing.

Not all parts will require shrink control. For those that do and depending on part shape, place in shrink fixtures for whatever amount of time is necessary. Thicker parts tend to require more time in the fixture than thinner parts. There are no real rules of thumb – experimentation with the actual part is the norm. Shrink fixture dwell time is usually stated on the shop floor by number of shots, for example, 'retain in fixture for five shots'. Control of shrink fixture dwell time can be handled in the following ways:

a. Shrink table, with manually operated clamps. Operator keeps track of where coolest part is, replacing it with a fresh from the mould part. Least desirable.

b. Carousel or turntable shrink fixture. Operator indexes the table each shot, removing and replacing parts in rotation.

c. Indexing conveyor, as part of an automatic finishing line.

5. Parts handling – conveying

The first consideration is whether the part to be conveyed has been deflashed or not. Deflashed parts generally can be moved with simple, single speed, constant running belt conveyors without problems. Conveying 'fresh from the mould' parisons with hot flash tends to be the cause of rejects because the hot flash sticks to other parisons, or worse yet, to other parts. Depending on flash configuration, when conveying parts straight from the mould, parisons with hot flash must be cooled as soon as possible; conveyors with support rails for the flash are recommended. When parts are circumferentially flashed, conveyors with separators are required to guarantee that the hot flash from one part cannot touch an adjacent part or its flash.

6. Trimming and deflashing

Figure 10.4 Using a CNC router to automatically trim blow moulded panels

Reproduced with permission from Agri-Industrial Plastics, Fairfield, IA, USA.

These terms are reasonably synonymous in industrial and large part blow moulding and refer to flash removal. ‘Trimming’ is more descriptive in container blow moulding where blow domes are cut away. In some plants and for some products, computer numerically controlled (CNC) routers are used to trim flash and remove unwanted material automatically, versus manually, when part volumes are high enough to justify the cost of automation (see Figure 10.4). Router will cause serious injuries if it makes contact with any part of the body while it is rotating. CNC machines move rapidly and must never be approached while in operation. An alternative to the router is the laser. Laser cutting uses a powerful enough beam of light to cut plastic by heating and vaporizing a very small area. A laser is used to make highly accurate, intricate holes and complex patterns. The laser power can be adjusted to just etch the surface of the plastic, or to penetrate deeply, even drill through. Laser cutting provides a clean, finished appearance and is more precise than conventional cutting methods. Never look into a laser when it is on, or when it could be turned on at any time. Laser protection goggles must be worn at all times to avoid serious eye damage when working with high power laser cutting equipment. As with CNC robotic routers, stay away from the machine while the head is active, even if it is not moving at the moment. A third alternative for making complex, precise trimming cuts is the water jet. While it may seem as impossible to cut with water as to cut with light, water-jet cutters use a thin jet of water at pressures up to 379 MPa to quickly cut the toughest plastics. Water-jet cutting is very accurate, creates no smoke or dust, and produces a relatively smooth cut edge. As with a laser, most water-jet cutters are mounted on a robot or a rotating head. Personal protective equipment will not protect against close contact with the high-pressure jet. Do not go near the water-jet cutter nozzle unless the machine has been turned off and locked out. Even with the introduction of robotic devices for flash removal and trimming, the most common method of flash removal with large industrial parts is manual, using a knife to trim and a hammer to remove the parison tail. Increasingly in the high-speed production of containers, machine de-flashing is used. While each application has its own requirements, most employ an assortment of pneumatic and hydraulic de-flashing presses. A common deflash press uses female bottom nests into which the parts are placed. For the most part, these presses are semi-automatic, operator loaded, and unloaded. The majority are simple designs with nests mounted on tables. A few have channels for the scrap to drop to a conveyor below. Parts with circumferential flash cannot ordinarily be trimmed in this way. Where interior flash webs must be removed, the bottom nest includes a die or cutout. The top tooling includes a punch. De-flashing presses may be either bottom or top acting. The part, cradled in the nest, contacts the de-flashing die, which over-strokes slightly. A top acting stabilizer/ejector member is generally required. For head and tail flash, as well as circumferential flash, the tooling will vary depending on whether or not the parting line is flat or irregular. Flat parting lines are well handled by a die plate. The flash to be removed rests on a hard, smooth surface, and a sharpened blade in the shape of the area to be trimmed is pressed with considerable force against the plastic, cutting through it and coming into contact with the die plate below. Irregular parting lines are better handled by ‘opposed chisel’ tooling, which works by shearing the plastic between two sharp edges. A feature common in deflashing machinery is the guillotine, which is used to chop-off blow channels and neck-like areas. Guillotine cutters work like the ancient capital punishment devices, but usually have an air or hydraulically assisted fall (moving blade) to ensure proper cutting every time. Guillotine cutters are available in manual or automatic models. Because of their size and the difficulty of adequately guarding the blade, they are carefully designed and include several safety devices. Some include photo eyes that detect the thickness of what is under the guillotine. If the thickness is too great, the machine will not function. All systems guard the blade area, and to ensure that the operator is safely away from the cutter some machines have pressure mats that must detect a human’s weight before the blade will move. Some manual systems require two distant buttons to be pushed to ensure that the operator’s hands are safely away from danger. There is a category of secondary equipment referred to as ‘fixtures’. Generally, fixtures are job specific for a specific part and designed for secondary machining. Some ‘fixtures’ include deflashing, both partial – an interior section needs to be punched out – and complete exterior deflashing.

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Plastic Extrusion - Operation, Shutdown and Maintenance Procedures: https://www.youtube.com/watch?v=Rf5DQR5qXxU
Extrusion Blow Molding - Lesson 3 - Extrusion Blow Molding Operating Controls: https://www.youtube.com/watch?v=YWzaZYHXS9s
Processing of Plastics- Compression and Transfer Moulding: https://www.youtube.com/watch?v=A1XKGUH7wRQ
What is Compression moulding process in hindi: https://www.youtube.com/watch?v=NlJqDPlnDXY
Compression Moulding Process: https://www.youtube.com/watch?v=sus8arkJOeA

Summary – overview of the curriculum

Module Title and Aim	Learning Units	Timeframe of modules
Module 1: Contribute to Work Related Health and Safety (WHS) Initiatives **Aim:** This unit describes the skills and knowledge required to manage the identification, review, development, implementation and evaluation of effective participation and consultation processes as an integral part of managing work health and safety (WHS).	**LU1.** Contribute to initiate work-related health and safety measures **LU2.** Contribute to establish work-related health and safety measures **LU3.** Contribute to ensure legal requirements of WHS measures **LU4.** Contribute to review WHS measures **LU5.** Evaluate the organization's WHS system	30
Module 2: Comply with Workplace Policy and Procedures **Aim:** This unit describes the skills and knowledge required to implement a workplace policy & procedures and to modify the policy to suit changed circumstances. It applies to individuals with managerial responsibilities who undertake work developing approaches to create, monitor and improve strategies and policies within workplaces and engage with a range of relevant stakeholders and specialists.	**LU1.** Manage work timeframes **LU2.** Manage to convene meeting **LU3.** Decision making at workplace **LU4.** Set and meet own work priorities at instent **LU5.** Develop and maintain professional competence **LU6.** Follow and implement work safety requirements	30

Module Title and Aim	Learning Units	Timeframe of modules
Module 3: Perform Advanced Communication **Aim:** This unit describes the performance outcomes, skills and knowledge required to develop communication skills used professionally. It covers plan and organise work and conduct trainings at workplace, along with demonstrating professional skills independently	**LU1.** Demonstrate professional skills **LU2.** Plan and Organize work **LU3.** Provide trainings at workplace	30
Module 4: Develop Advance Computer Application Skills **Aim:** This unit provides an overview of Microsoft Office programs to create personal, academic and business documents following current professional and/or industry standards, i.e. Data Entry, Power Point Presentation and managing data base and graphics for Design It applies to individuals employed in a range of work environments who need to be able to present a set range of data in a simple and direct forms	**LU1.** Manage Information System to complete a task **LU2.** Prepare Presentation using computers **LU3.** Use Microsoft Access to manage database **LU4.** Develop graphics for Design	40

Module Title and Aim	Learning Units	Timeframe of modules
Module 5: Manage Human Resource Services **Aim:** This unit describes the skills and knowledge required to plan, manage and evaluate delivery of human resource services, integrating business ethics. It applies to individuals with responsibility for coordinating a range of human resource services across an organization. They may have staff reporting to them.	**LU1.** Determine strategies for delivery of human resource services **LU2.** Manage the delivery of human resource services **LU3.** Evaluate human resource service delivery **LU4.** Manage integration of business ethics in human resource practices	20
Module 6: Develop Entrepreneurial Skills **Aim:** This Competency Standard identifies the competencies required to develop entrepreneurial skills, in accordance with the organization's approved guidelines and procedures. You will be expected to develop a business plan, collect information regarding funding sources, develop a marketing plan and develop basic business communication skills. Your underpinning knowledge regarding entrepreneurial skills will be sufficient to provide you the basis for your work.	**LU1.** Develop a business plan **LU2.** Collect information regarding funding sources **LU3.** Develop a marketing plan **LU4.** Develop basic business communication skills	30

Module Title and Aim	**Learning Units**	**Timeframe of modules**
Module 7: Perform Off Tool Sampling **Aim:** This competency standard identifies the competencies required to perform off tool sampling in accordance with job order/sheet's guidelines. You will be expected to carry out off tool sample, ensuring cost effectiveness, conforming to standards and regulations. The underpinning knowledge regarding off tool sampling will be enough to provide the basis for your work.	**LU1:** Ensure type of Tool **LU2:** Set Machine Parameters **LU3:** Execute Dry Run Operation **LU4:** Produce Sample **LU5:** Verify Sample Specification **LU6:** Generate Sample Report **LU7:** Take Approval for Processing	150
Module 8: Perform Tool Change over **Aim:** The standard covers specific knowledge related to operation of tool change procedure, installation and explaining parameter setting, and reporting procedure of machine.	**LU1:** Obtain Work Order according to Standard **LU2:** Prepare took for Production **LU3:** Carry out Tool Installation **LU4:** Carry out Tool Storage	150

Module Title and Aim	Learning Units	Timeframe of modules
Module 9: Perform Shutdown Procedure **Aim:** This competency standard is designed to provide skills and knowledge to performance shutdown procedures to machine in accordance with the manufacturer's Manual. You will be able to perform arrangement of tools, shutdown as planned, and emergency shutdown as per machine requirement. The standard covers specific knowledge related to operation of shutdown procedure, and reporting procedure of machine.	**LU1:** Arrange Tools and Accessories **LU2:** Perform Planned Shutdown **LU3:** Perform Emergency Shutdown	100
Module 10: Manage Product Quality **Aim:** This competency standard is designed to provide skills and knowledge to manage product quality, in accordance with inspection procedure, irregularities, quality acceptance, of quality control department. You will be able to report quality inspection and facilitate quality audit process. The underpinning knowledge regarding quality management and procedure of quality audit of sample and production will be enough to provide the basis for your work.	**LU1:** Perform Inspection **LU2:** Identify Irregularities As Per Standard **LU3:** Apply Acceptable Quality Level to Product **LU4:** Prepare Quality Inspection Report **LU5:** Facilitate in Auditing	120

Module Title and Aim	Learning Units	Timeframe of modules
Module 11: Manage Production Flow **Aim:** This competency standard is designed to provide skills and knowledge to manage production flow of machine in accordance with the manufacturer's Manual. You will be able to perform planning of production schedule, ensuring of raw material and accessories, verify data sheet of machine and prepare production report. The standard covers specific knowledge related to management of production workflow, identifying bottlenecks and rectifying them.	**LU1:** Plan Production Schedule **LU2:** Ensure Raw Material & Accessories **LU3:** Ensure the Machine Data Sheet **LU4:** Prepare Production Report	100

Short Questions/Answers

Q1. What Are the Important Characteristics of Plastics?	It can be molded into finished product by application of heat and pressure.
Q2. What Are the Advantages of Plastics Over Metals?	• Low weight • Corrosion resistance • Insulation properties • Electrical properties • Cheaper • Easy to handle • Surface properties • Reusable
Q3. What is the difference between parallel and conical twin screw extruders?	Conical twin screws are used for better throughput and parallel twin screws are used for better mixing.
Q4. Explain the Disadvantages of Plastics?	• Low strength • Low heat resistance • Poor mechanical properties • Difficulty to repair
Q5. Types of Plastics Based on Chemical Behavior?	• Thermo plastics • Thermosetting plastics
Q6. Difference Between Thermoset and Thermoplastics?	Thermoplastics: • Can be re softened and reused • No chemical changes during heating. • In granular form • Needle structure • Hard but not brittle Thermo set plastics: • Cannot be re softened and reused • Chemical changes during heating etc. • In powder form

	• Cross linked structure • Hard and brittle
Q7. What is MFI?	Flow capacity of different grades of thermoplastics are inversely proportional to molecular weight.
Q8. Examples for Thermosetting Materials?	Alkyds, epoxies, pf, mf, urea, polyester, etc.
Q9. What are Fillers and Additives?	Adding of small molecules to plastics to get some characteristics (color, flexibility etc.). Fillers are commonly used with thermosetting plastics. Additives are of two types, • Physical means such as plasticizer • Chemical means--- stabilizer.
Q10. What are the Mold Release Agents?	• External with mold surface e.g. Polyvinyl alcohol • Internal with resins e.g. Silicon oil
Q11. What are the Types of Injection Molding Machines?	• Plunger injection cylinder • Two stage plunger injection cylinder • Pre plasticizer two stage screw injection cylinder • Reciprocating screw injection cylinder
Q12. What are the Divided Sections of Screw of Injection Molding Machines?	• Feed zone • Compression zone • Melting zone
Q13. What do you mean by Nozzle?	Nozzle connected to the end of the barrel through which soften materials inserted in the mold.
Q14. What are the Types of Nozzle?	• Reverse taper (melt valve) - for PA, ABS, etc. • Removable tip • Standard of general purpose
Q15. Define Drooling?	Leakage of plastic material through the nozzle in between shots.
Q16. What is Injection Capacity or Short Capacity?	Maximum volume material injected by the screw during one cycle of operation.

Q17. What is Plasticizing Capacity?	It is the amount of material that can be processed by the machine per hour. It is expressed in kg/h.
Q18. What is Injection Pressure?	It is the maximum pressure by which the material is injected through the nozzle. It is given in kg/cm^2.
Q19. What is Injection Rate or Injection Velocity?	It is the maximum rate at which the screw can inject or shoot materials from the barrel during one shot.
Q20. What do You Meant by Clamping Force?	It is the maximum force that the clamping system can exert on the mold or it is the maximum force by which the mold halves can be closed together. It is given in ton or kilo Newton.
Q21. What is Maximum Daylight?	It is the maximum distance that the machine platen can be separated from each other and it can be obtained by adding the maximum mold thickness to the maximum opening stroke.
Q22. What is a Mold?	It is a custom build tool in which converts plastic raw material into finished product.
Q23. What are the Main Elements of Mold?	The main parts of molds are core and cavity.
Q24. What are the General Types of Mold?	Injection molds, compression molds, transfer molds.
Q25. What are the Types of Injection Mold?	• Two plate mold • Three plate mold • Hot runner mold • Insulated runner mold • Hot manifold mold • Stacked mold
Q26. What is Two Plate Mold?	Mold which consists of core and cavity situated in plates. It is logical type tool where component require large gate. For simple type components there is only one daylight.
Q27. What is 3 Plate Mold?	It consists feed plates with core and cavity.
Q28. What is Hot Runner Mold?	In this, runner kept hot to keep the molten metal into fluid state also called runner less mold. In this, runner contained in a plate of its own runner section of the mold is not opened during molding cycle.
Q29. Note down the Advantages of Runner Mold?	• No molded side products

	• No separating of gate • Cycle time can be reduced
Q30. What is Insulated Runner Mold?	It is a variation of hot runner mold in this type of molding. The outer surface of the material in the runner acts as a insulator.
Q31. What is Hot Manifold Mold?	This is a variation of the heated hot runner and not the runner plate. This is done using electric cartridge.
Q32. What do You Meant by Stacked Mold?	A stacked mold is a multiple two plate mold with mold placed one over the other. A stacked mold construction doubles the output from a single molding machine and requires the same clamping force.
Q33. Explain about Injection Molding?	In this process, the plastic material is injected in to the mold through a sprue bush by means of a screw plunger. This process can be used for both thermosetting and thermoplastic materials.
Q34. What is Compression Molding?	In this process, the plastic material is placed in the cavity and use a force for compressing the compound as the mold closes, these molds are generally used for thermosetting materials.
Q35. What is Transfer Mold?	In this process, the plastic material is transferred from a transfer pot and then forced in to the cavity by means of plunger. This method is used for molding thermosetting materials only.
Q36. Explain Vacuum Molding?	The mold used for this process is similar that of the female half of the compression or blow mold auxiliary equipment on the machine heats the material and drags it over the cavity as indicated by the precise technique chosen.
Q37. What do You Meant Cavity?	Female portion of the mold and it gives external form.
Q38. What is Core?	Male portion of the mold and it gives internal form.
Q39. What is Sprue Bush?	Connecting member between register ring and runner.
Q40. What is Gate?	Connecting member between impression and runner.
Q41. What is A Quality Management Plan (QMP)?	A QMP is a formal plan that documents an entity's management system for the environmental work to be performed. The QMP is an "umbrella" document which describes the organization's quality system in terms of the organizational structure, functional responsibilities of management and staff,

	lines of authority, and required interfaces with those planning, implementing, and assessing all environmentally related activities conducted.
Q42. What are the Benefits of Quality Management System?	• Improvement in internal quality (reduction in scrap, rework and non-conformities in the shop) • Improvement in external quality (customer satisfaction, claims of non-conforming products, returned products, warranty claims, penalty claims etc) • Improvement in Production reliability (number of break downs, percentage down time etc) • Improvement in Time performance (on-time delivery, time to market etc) • Reduction in the cost of poor quality (external non-conformities, scrap, rework etc)
Q43. In the region, where there is no Quality Management, what would you do to introduce the concept of TQM?	Where Quality processes are not available, I would encourage them to identify and document their each and every task for each process. Then, I would encourage them to define and document what they can do for minimizing human or machine errors. I would encourage them to identify wastage's like material or time wasters and define process to minimize these wastages. I would ask them to record and document each finding and strive to improve each process.
Q44. What is the difference between Quality Assurance and Quality Control?	**Quality Assurance:** ○ It is an Assurance activity, emphasizing on the standards and procedures to be followed while developing an application ○ It is a Preventive action taken before hand to ensure the product that developed are defect free ○ It is a systematic action necessary to provide enough confidence that a product or service will satisfy the given requirements for quality. **Quality Control:** ○ It is a Corrective action ○ Inspection if the developed application follows the standards and procedures by using the checklists.

Q45. Differentiate between Product Quality and Process Quality?	Product quality means we concentrate always final quality but in case of process quality we set the process parameter
Q46. What does 6 Sigma Represent?	Meaning 99.999997% perfect; only 3.4 defects in a million.
Q47. How might the Operations Manager (you) be Involved with Individual Employees Morale?	Oftentimes this question gauges whether someone understands the position of operations manager and has a decent understanding of what scope the job entails. An operations manager has to deal with small scale conflicts, discipline, and office regulations. Oftentimes this means effectively communicating with/being attentive to, individual employees to ensure that personal conflicts or grievances are allayed. Be prepared to be asked about specific examples where a decision that you made influenced a situation either positively or negatively.

Test Yourself (Multiple Choice Questions)

MODULE	7			
Question	**1**	Three overall classes of plastics are distinguished from one another. They include thermosets, thermoplastics and ___________________	A	Monomers
			B	Synthesis
			C	Elastomers
			D	Fibers
Question	**2**	Thermoplastics are soluble and ________	A	Densely cross-linked
			B	Fusible
			C	Non-fusible
			D	Crystalline

Question	**3**	Amorphous thermoplastics are _________ when they are not combined with fillers or similar additives.	A Transparent B Milky opaque C Translucent D Black
Question	**4**	Polycarbonate (PC), from which Compact Disks are molded, is a(n) __________ thermoplastic.	A Amorphous B Semi-crystalline C Liquid Crystal D Immiscible
Question	**5**	____________ cannot be fused or dissolved but can be swelled.	A Thermoplastics B Elastomers C Thermosets D Composites

Question	**6**	Thermosets are non-fusible and ____________	A	Soft
			B	Densely cross-linked
			C	Dense
			D	Irregular shaped
Question	**7**	The intermolecular forces which operate in the crystalline state are considerably ___________ than those in the amorphous state.	A	Weaker
			B	Stronger
			C	Complex
			D	Diverse

Question 8 The abbreviation for polyamide, as specified by IS0 1043, is __________________

A PS

B PA

C PC

D PVA

Question 9 Processing temperatures are _________ for thermoplastics than for metals.

A Higher

B Lower

C Left

D Right

Question 10 Viscosity is a measure of the __________ of a melt.

A Hardness

B Flow properties

C Density

D Visco-elasticity

Question	**11**	As temperature decreases, the viscosity of the melt __________________	A	Increases
			B	Decreases
			C	Varies
Question	**12**	The injection Moulding process can be divided into the following phases: injection, holding pressure, cooling, feeding and ________________.	A	Locking
			B	Removal
			C	Cleaning
			D	Closing

Question	**13**	The nozzle is ____________ during the injection phase.	A Closed B Open C Perforated D Ejected
Question	**14**	The screw moves towards the ______________ during the injection phase.	A Hopper B Nozzle C Pump D Motor
Question	**15**	Compensation for shrinkage occurs during the _____________ phase.	A Injection B Holding pressure C Feed D Metering

Question	**16**	The ________ phase runs concurrently with the feed phase.	A	Cooling
			B	Injection
			C	Holding pressure
			D	Metering
MODULE	**8**			
Question	**17**	Which of the following material is not used in extrusion?	A	Wax
			B	Granules
			C	Powder
			D	Pellets
Question	**18**	In blow molding, to inflate soft plastic, which medium is used?	A	Air
			B	Water
			C	Oil
			D	Alcohol

Question	**19**	Which of the following plastics is not used in blow molding?	A	Terephthalate
			B	Polyethylene
			C	Polypropylene
			D	PVC
Question	**20**	Which of the following is not a type of blow molding process?	A	Injection Blow Moulding
			B	Extrusion Blow Moulding
			C	Multi-smaller blow moulding
			D	Multi-larger blow moulding
Question	**21**	What is the minimum thickness required by the plastic for vacuum forming?	A	0.125mm
			B	0.25mm
			C	0.375mm
			D	0.5mm

MODULE	9			
Question	**22**	Which of the following material is not used in purging?	A	Wax
			B	PE
			C	PP
			D	PC
Question	**23**	What is the ideal temperature for purging?	A	230°C
			B	190°C
			C	250°C
			D	T_g
Question	**24**	Purging is done to remove what from machines?	A	Contaminants
			B	Residual material
			C	Burnt material
			D	All of the above

MODULE	10			
Question	**25**	What was the transcendent view of quality?	A	Satisfying customers
			B	Meeting needs and wants
			C	Innate excellence
			D	Conformance
Question	**26**	What the organization must accomplish to achieve the mission, by examination and categorization of the impacts?	A	Critical success factors
			B	Key process indicators
			C	Legal and policy factors
			D	The enemy indicator

Question	**27**	Which of the following should be used as input to management review in order to ensure that continual improvement is the driver for organizational development?	A	Performance information
			B	Performance management
			C	Ethical performance
			D	Performance development
Question	**28**	Which of the following statements holds true for quality assurance?	A	Top management's intention regarding quality
			B	Functions determining implementation of the quality policy
			C	Actions to provide confidence of satisfying quality requirements
			D	Responsibilities and processes, which implement quality management
Question	**29**	Which of the following models has a vertical chain of command?	A	Organism model
			B	Mechanistic model
			C	Cultural model
			D	Total quality model

MODULE	11			
Question	30	Operations management involves the functions of planning, organizing, controlling etc, in production systems. The activity of encouraging employees through praise, recognition and other intangibles is part of which function?	A	Controlling
			B	Motivating
			C	Coordinating
			D	Organizing
Question	31	Decisions on production and process design, facility location and layout etc, are part of which decision category?	A	Strategic decisions
			B	Tactical decisions
			C	Operational decisions
			D	All of the above
Question	32	The decision of an operations manager about what products to make and when is part of which function?	A	Organizing
			B	Directing
			C	Planning
			D	Coordinating

Question	**33**	Operations Management involves the activities of planning, organizing, controlling, directing, and coordinating in production systems. These systems convert resource inputs into products or services. Centralization and/or decentralization of operations fall under which of the following activities?	A	Organizing
			B	Directing
			C	Planning
			D	Coordinating
Question	**34**	Who generally develops corporate objectives that are unique to each organization?	A	Front line managers
			B	Top-level managers
			C	Middle level managers
			D	Production supervisors
Question	**35**	What is the basic use of a prototype during the new product development process?	A	A prototype is used to test the technical and economical feasibility
			B	A prototype helps test the product performance under standard conditions
			C	A prototype is developed as part of test marketing
			D	None of the above
Question	**36**	Work standards techniques generally find use in which of the following operations?	A	Operations planning
			B	Operations scheduling
			C	Operations control
			D	All of the above

Question 37 Organizations generally use demand forecasts to develop which of the following plans?

A Financial plans

B Facilities plan

C Marketing plans

D All of the above

Multiple Choice Questions Answer scheme

Module 7:

Q1: C
Q2: B
Q3: B
Q4: B
Q5: C
Q6: B
Q7: B
Q8: B
Q9: B
Q10: B
Q11: A
Q12: B
Q13: B
Q14: B
Q15: B
Q16: D

Module 8:

Q17: A
Q18: A
Q19: A
Q20: C
Q21: C

Module 9

Q22: B
Q23: A
Q24: D

Module 10

Q25: D
Q26: B
Q27: A
Q28: C
Q29: A

Module 11

Q30: B
Q31: A
Q32: C
Q33: A
Q34: B
Q35: B
Q36: C
Q37: A

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